COLORADO GEOLOGICAL SURVEY
BOULDER

R. D. GEORGE, State Geologist

BULLETIN 18

FLUORSPAR DEPOSITS OF COLORADO

By
HARRY A. AURAND

DENVER, COLORADO
EAMES BROTHERS, STATE PRINTERS
1920

GEOLOGICAL BOARD.

His Excellency, Oliver H. Shoup................Governor of Colorado

George Norlin..................................President University of Colorado

Victor C. Alderson.......................President State School of Mines

Charles A. Lory.....................President State Agricultural College

LETTER OF TRANSMITTAL.

State Geological Survey,

University of Colorado, April 29, 1920.

Governor Oliver H. Shoup, Chairman, and Members of the Advisory Board of the State Geological Survey.

Gentlemen: I have the honor to transmit herewith Bulletin 18 of the Colorado Geological Survey.

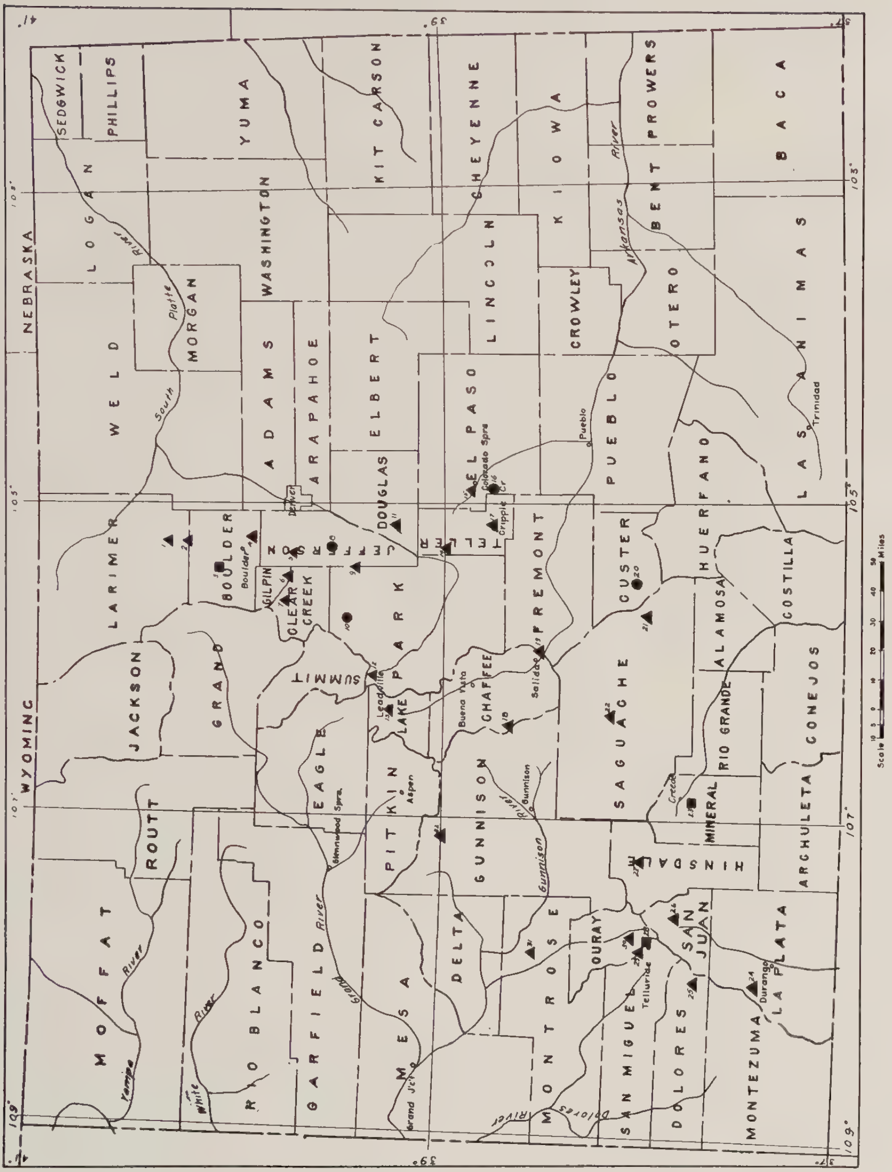
Very respectfully,

R. D. GEORGE,
State Geologist.

CONTENTS

LEGEND.

1—Big Thompson
2—Allen's Park—St. Vrain
3—Jamestown
4—Eldorado Springs
5—Bergen Park—Clear Creek
6—Idaho Springs—Central City
7—Georgetown—Silver Plume
8—Evergreen
9—Buffalo
10—Jefferson
11—Devil's Head
12—Alma
13—Leadville
14—Florissant
15—Pike's Peak—Cascade
16—St. Peter's Dome—Cather Springs
17—Cripple Creek
18—Mt. Antero
19—Badger Creek
20—Antelope Creek
21—Liberty
22—Bonanza
23—Wagon Wheel Gap
24—La Plata Mountains
25—Rico
26—Silverton
27—Lake City
28—Red Mountain
29—Telluride
30—Ouray
31—Montrose
32—Crystal
33—Powderhorn



MAP SHOWING DISTRIBUTION OF COLORADO FLUORSPAR

■ Commercial Deposits.

● Probable Commercial Deposits.

▲ Non-Commercial.

Fluorspar occurs as gangue mineral in ores or as individual crystals.

PREFATORY

During the spring and early summer of 1917 the State Geologist applied through the newspapers of the State, and by specially prepared notices, for information concerning workable deposits of certain minerals for which the war had caused an increased demand.

Persons knowing of such minerals were asked to send in samples together with a description of the deposit from which they were taken. If the sample and the description of the deposit seemed to warrant an investigation, a member of the Colorado Geological Survey was then sent to make an examination of the deposit. The data obtained from the investigation was filed in the office of the Colorado Geological Survey, and if a deposit proved promising a report was then presented to the proper United States official. Information concerning producing and workable deposits of these minerals was in this way made immediately available to the proper board in Washington.

MINERALS NEEDED BY THE U. S. GOVERNMENT

The Colorado Geological Survey is co-operating with the U. S. Government in an attempt to find workable deposits of certain minerals for which the war has caused an increased demand. Among these materials are: Ores of molybdenum (free from copper), ores of vanadium, uranium, nickel, manganese and platinum. Transparent, unfractured fluorspar in fairly large pieces, and as nearly colorless as possible is also needed. Pale green and very pale purple colors may not prevent its use if it is otherwise satisfactory.

Persons knowing of deposits of any of these ores should write to R. D. George, State Geologist, Boulder, Colo., sending an average sample of the ore if possible, and describing the deposit. If the sample and description appear to warrant further investigation the state geologist or someone appointed by him will examine the deposit without expense to the owner. If it should prove promising a report will be presented to the proper United States officials.

Prospectors and others not familiar with these ores will find descriptions of them in Bulletin 6 of the Colorado Geological Survey. This is now out of print, but Bulletin 12, covering much the same ground, will be sent to those who have not had Bulletin 6.

The Survey may be able to furnish small fragments of the commoner ores to a few prospectors. But unless they are really needed they should not be asked for as only a very small amount of the material can be spared.

(Signed) R. D. GEORGE,
State Geologist.

Deposits which were producing or had formerly produced any of the required minerals were investigated, and a careful analysis was made of the possibilities of each deposit as a source of immediate production.

As a result of these investigations a large amount of valuable information has been obtained, which should prove of real economic value even after the demands created by the war no longer exist. This bulletin presents the information gathered in the search for fluorspar.

Fluorspar Deposits of Colorado

CHAPTER I

INTRODUCTION

The greatly increased demands for Fluorspar since the beginning of the European War have caused a corresponding increase in the price of this non-metallic mineral which formerly had only a moderate value and for which there was only a limited demand. The demand has been stimulated on account of its extended use in metallurgical, chemical and ceramic industries; the greatest demand for it being made by the steel and chemical industries, where it is used principally in the manufacture of open hearth steel and hydrofluoric acid.

This demand with the resultant higher prices has stimulated a renewed interest in the fluorspar mining industry in Colorado. Mines which have been producing intermittently for years are now being worked with renewed energy, others which have been closed down for years are now being re-opened, and new mines and entirely new deposits are constantly being opened.

The milling of fluorspar is being tried for the first time in Colorado, and one company is successfully operating a commercial mill in Boulder. Other companies are contemplating the milling of their ores, and three of them have carried on experimental tests with a view to the installation of milling machinery.

LOCATION OF FLUORSPAR DEPOSITS

The fluorspar deposits of Colorado are found mainly in a belt roughly paralleling the eastern side of the Front Range. Several disconnected but equally productive areas occur in the southern and southwestern parts of the state, and other deposits of no economic value are found scattered throughout the mountainous portions of the state.

With the exception of those deposits in the San Juan district no deposits of economic value are found on the western slope.

Comparatively few specimens from that part of the state have come to the attention of the writer, and they gave no promise of commercial value.

Fluorspar is found exposed on a number of the streams forming the drainage on the eastern side of the Front Range. It is these deposits which form a belt roughly paralleling the Front Range, extending from the South St. Vrain in Boulder County south to St. Peters Dome and Cather Springs in El Paso County.

A second series of deposits, not so well defined and of much less extent, is to be found much closer to, but roughly paralleling the Front Range. These are shown by the presence of fluorspar in the ores of the Clear Creek, Cripple Creek and Alma districts, near Jefferson, Park County; Florissant, Teller County; and on Antelope Creek in Custer County.

A third district includes those deposits in the San Luis Valley where fluorspar is found on the west side of the Sangre de Cristo Range near Liberty, Saguache County; on the east side of the Continental Divide at Bonanza, Saguache County; and at Wagon Wheel Gap, Mineral County.

A fourth region includes the San Juan district where fluorspar is found both in commercial quantities and as a gangue mineral in the ores of the various camps throughout the district.

A small deposit of no commercial value is found on the south side of the Black Canyon of the Gunnison on Vernal Mesa near Montrose. Other scattered deposits of the mineral were noted, where it is found as a gangue mineral in the ores of the Crystal (Gunnison Co.,), and Leadville mining districts.

THE FLUORSPAR INDUSTRY IN COLORADO

In 1869, F. V. Hayden reported the presence of fluorspar in the ores of the Baker mine[1] located four miles above Georgetown in a canyon known as the West Argentine. Red and white varieties of fluorspar occurred largely as a gangue in the lode.

Again in 1878, F. V. Hayden reported the presence of fluorspar in the Terrible mine at Georgetown;[2] on Mt. McClellan and Gray's Peak; in the Sweet Home mine, Leadville; at Jamestown; and on Kendall Mountain near Howardsville, San Juan County.

[1]Hayden, F. V., Geographical survey of the territories: U. S. Geol. Survey, 3rd Ann. Rept., p. 209, 1869.

[2]Hayden, F. V., Geographical survey of the territories: U. S. Geol. Survey, 10th Ann. Rept., pp. 142-143, 1876.

In his biennial report for 1880 the State Geologist of Colorado reports occurrences of fluorspar as follows: At Jamestown, Boulder County, massive deposits in which visible grains of free gold were occasionally found; in large metalliferous veins on Bear Creek, Jefferson County; and in the silver mines of Argentine and Georgetown.

The actual mining of fluorspar in Colorado appears to date back to the early ''seventies,'' when fluorspar was mined from the deposit on Cub Creek, southwest of Evergreen, Jefferson County, and carted 28 miles to the Central City district[3] where it was used as a flux in the smelting of the gold and silver ores of that district. The mines produced about 600 tons of fluorspar[4] which was sold to the Boston and Colorado smelter at Black Hawk before it was removed to Argo.

H. N. Coffey is reported to have shipped fluorspar from the Poorman claim at Jamestown, Boulder County, as early as 1873 or 1874. This property had been opened for gold which did not occur in paying quantities, and as there was a limited demand for fluorspar, a small tonnage was hauled to the Boyd smelter at Boulder. After standing idle two or three years the shaft was repaired and other shipments were made to Boulder, where it was used as a flux in smelting the gold and silver ores of the Boulder district. The price was $5.00 per ton.

The fluorspar deposits on Cub Creek and at Jamestown were worked very irregularly. In 1905 it was estimated that Colorado had produced less than 6,000 tons. [5]The greater part of this production had come from the Jamestown district where development, although very slow, had progressed somewhat.

The inability of the miner to sort the material and make a high-grade product, the distance from the railroads, the high cost of haulage, and the low price made the mining of fluorspar unattractive. Metalliferous mining was much more inviting to the miner in those districts, and his chances for profit were far better.

Because of the high freight rates, the high cost of mining, and the low grade of the product, Colorado fluorspar could not compete on the eastern market with that from the Illinois-Kentucky fields, and that imported from Europe. The Colorado deposits had not been developed enough to show their possible production. Transportation to railroad was slow and costly, and no milling or sorting

[3]Burchard, Ernest F., Min. & Sci. Press, p. 258, Aug. 21, 1909.
[4]Williams, Albert, Jr., U. S. Geol. Survey, Min. Res., p. 587, 1882.
[5]Burchard, Ernest F., U. S. Geol. Survey, Min. Res., pp. 1099-1103, 1905.

facilities had been installed to guarantee a uniformly high grade product, such as was necessary to insure a good market. As a result, practically the only market for Colorado fluorspar was that furnished by the Colorado Fuel & Iron Company at Pueblo. As the available market for fluorspar was limited and the margin of profit exceedingly small no great progress was made in the industry. When there was little or no activity in metal mining, and an unusually promising deposit of fluorspar was found, the output of the State would increase.

These conditions prevailed up to 1915 when there was produced in the State a total of less than 1,000 tons of fluorspar. In 1916 greater demand and higher prices stimulated interest in the industry, and a corresponding increase in production followed. In 1917 there were one or more producing mines in six different districts. One mill was producing concentrates, and much experimenting in processes of milling was in progress. Mines were being opened in several entirely new districts. In the spring of 1918 practically all the mines which had produced in 1917 were again open, and in the Jamestown district many new mines were operating. Three mills were producing concentrates and preparations were being made for the operation of others.

ACKNOWLEDGMENTS

In presenting this report the writer desires to express his thanks and acknowledge his indebtedness to all who by their courteous treatment aided so materially in the gathering of much valuable data. He is especially indebted to John Evans of Jamestown, S. B. Collins of Creede, C. R. Wilfley of Ouray, and D. W. Phillips of Wagon Wheel Gap who gave much time and many valuable suggestions.

SCOPE OF THE FLUORSPAR INVESTIGATION

In the investigation of the various fluorspar deposits, special attention was paid to the location, size and character of the deposit, as well as to the production, or possible production under properly applied methods. Each deposit was examined carefully for the presence of optical fluorspar, and many smaller deposits, of no commercial value so far as production was concerned, were visited in the hope that optical material might be found.

GEOGRAPHY

Colorado fluorspar deposits are, with one exception, very poorly situated so far as transportation facilities are concerned. Those larger deposits along the Front Range at Jamestown, Boulder County; Bear Creek, Jefferson County; and Antelope Creek, Custer County are located four to sixteen miles from a railroad. The Barstow mine at Red Mountain while but one mile from the railroad, can depend on that road only five months out of the year. During the other seven months it must haul the ore fourteen miles to Ouray, over the most treacherous of roads. The Wagon Wheel Gap deposit can be worked the year round, is located one and a quarter miles from the railroad, and is connected with it by a tram. This is the only deposit of any size which is at all well situated so far as railroad transportation is concerned.

The building of good roads suitable for truck haulage will eventually solve the transportation problem in several localities where the construction of a railroad is not now justifiable.

The southwestern part of the State suffers through the lack of standard gauge railroads, the high cost of the present mode of transportation, the short period during which the deposits can be worked each year, and the difficulties experienced in shipping during the winter months.

CHAPTER II

THE FLUORSPAR INDUSTRY IN COLORADO

Up to the present time the Colorado producers of fluorspar have been unable to compete with eastern producers either in the eastern markets or in the local market furnished by the Colorado Fuel & Iron Company at Pueblo. This has been due to the following facts and conditions:

1. The meager development of the fluorspar deposits.
2. A lack of proper mining equipment.
3. Carelessness or indifference in the grading of ores. The silica content is so high that the value of the ores is greatly reduced. Markets for such a product are exceedingly scarce.
4. The cost of hauling to railroads and the high freight rate to eastern markets.

IMPROPER DEVELOPMENT

The fluorspar deposits in most districts have been worked irregularly and with one end in view—that of getting out the greatest tonnage possible in a short time. The ore has been obtained by gouging and gophering and no proper development has been done. Caving results, much valuable ore is rendered inaccessible, and the miner seeks a new deposit and starts again.

MINING EQUIPMENT

Very little machinery has been used under the prevailing method of mining, whereas, in many cases a small expenditure on equipment would have been repaid many times by the results obtained.

GRADING OF FLUORSPAR ORES

Until 1917 no attempt was made to grade the ore shipped from the various camps, other than to hand cob and sort it before shipping. Many foreign materials such as quartz, clay, fragments of the granite side walls and gouge would get into the ore, and the percentage of calcium fluoride was so low that, in some cases, there was no market for the product, or the shipment was penalized so heavily for the high content of impurities that it did not pay the shipping charges.

Illinois and Kentucky operators have always been able to deliver an 85 per cent spar, with a silica content of less than 5 per cent. This standard has been reached in only a comparatively few shipments from Colorado districts, the main cause being the poor methods of grading used, and the lack of effort to eliminate this fault.

In Illinois and Kentucky the principal gangue mineral is calcite, a carbonate of lime, and the vein walls are mainly limestone. Neither of these adds to the silica content of the ores, whereas in Colorado the vein walls are granite or some other highly siliceous rock, and the principal gangue mineral is usually quartz, or material high in silica content.

The usual method of paying for Colorado fluorspar has been to fix a certain price per ton for fluorspar containing 85 per cent calcium fluoride and to give a premium for each additional per cent of calcium fluoride contained. In like manner the product was penalized for each per cent of calcium fluoride below 85. Buyers did not like to accept ore carrying less than 80 per cent calcium fluoride, and it was extremely difficult to dispose of it. This method was at times looked upon as unjust by the Colorado miner, but when it is remembered that, in the steel industry, an average of about 2.5 per cent of calcium fluoride is needed to neutralize 1 per cent of silica, it will be clear that a high percentage of silica is very detrimental, and that a high calcium fluoride content must be required.

During the summer of 1917 several cars of fluorspar having a high silica content, consigned to eastern buyers, were rejected even though the need of fluorspar at that time was exceedingly great.

By such experiences the miner was gradually impressed with the fact that the fluorspar ores would have to be graded more carefully, if he expected to find a ready market for his product. The milling of fluorspar was then started with a view to getting rid of the excess silica, and raising the calcium fluoride content.

MILLING OF FLUORSPAR

The simpler washing processes in vogue in the Illinois-Kentucky fields are not well adapted to most of the Colorado ores, as there is only a very slight difference between the specific gravity of the fluorspar and that of the quartz and feldspar forming the gangue. (Quartz 2.65, feldspar 2.70, fluorspar 3.13.) These methods could be used, but they would entail the installing of an elaborate system of screens and jigs. This would without doubt prove too expensive for the indivdual property which is not only small, but is working on a very close margin of profit.

Well equipped mills are standing idle in the Boulder County, Custer County, and San Juan districts, and there is no reason why methods of jigging and concentration should not be tried in all these districts. A small mill operated by the Hoffnung Mine and Milling Company has been milling the dump of the Argo mine at Jamestown, making a lead concentrate, and at the same time demonstrating the ease with which fluorspar may be concentrated. Early in the spring of 1918 this company adapted their equipment to the milling of fluorspar, and expected to commence commercial operations in May.

During the latter part of 1917 a commercial mill was opened in Boulder for the milling of Boulder County fluorspar. Truck service was installed between Boulder and Jamestown. The miner was paid for his ore according to the percentage of calcium fluoride it contained. A deduction was made to meet the haulage and loading charges.

On a recent visit to the Jamestown district the writer was told that the Wano mill, which has been idle for some years, was about to be remodeled and opened for the milling of fluorspar.

FLUORSPAR CONCENTRATES

It is reported that some users of fluorspar object to concentrates on the ground that, in use, there is great loss in the form of dust. With the increasing demands for fluorspar, there can be little doubt that methods will be adopted by which the concentrates may be used as effectively and economically as can lump and gravel fluorspar.

PRODUCING AND MARKETING

In order to overcome this handicap the Colorado deposits must not only be operated by the most economical methods, but the product must be constant in quality, and one on which the buyer can absolutely depend. The average miner or mine owner can not afford to operate a mill but must depend upon and cooperate with those who will mill and find a market for his ore. He must aid the shipper by having ready and actually furnishing his required tonnage at a specified time, as the buyer will likewise demand promptness of the shipper in his deliveries. The miner must be willing to accept a reasonable profit in the future, for while the war demands have created a high market value there will be a return to lower prices and more normal conditions.

GEOLOGY

The fluorspar deposits of Colorado are, with the exception of those at Rico, found entirely within areas of granite or other highly acidic rocks of igneous origin. The veins in Boulder County, Jefferson County, El Paso County, and Custer County are found in fissure veins, entirely within the granite. Their chief content is fluorspar, but at times the fluorspar content becomes negligible and the veins become mainly metalliferous. In some instances in Boulder County, fluorspar veins and metalliferous veins occur in the same district associated with porphyry dikes which have intruded the pre-Cambrian gneisses and granites.

In Mineral County and the San Juan district the veins occur within areas of highly acidic volcanic rocks of Tertiary age, mainly tuffs, rhyolite, latite and andesite.

Fluorspar occurs as a gangue mineral in some veins, but at Wagon Wheel Gap and in the Barstow mine at Red Mountain the vein filling is nearly pure fluorspar. Although the fluorspar vein in the Barstow mine lies in close proximity to metalliferous veins the material in the vein is very pure, and practically no fluorspar is found in the adjacent metalliferous veins. At Wagon Wheel Gap the vein filling is nearly pure fluorspar, though some barite is found locally near the surface. The wall rock, which is much more altered than in any of the other deposits mentioned, carries disseminated pyrite. The ores of most of the mining districts lying within igneous rock areas show the presence of fluorspar as a gangue mineral, while at Rico, fluorspar, although not of widespread occurrence, is abundant in the replacement deposits of the Black Hawk mine.

CHAPTER III

FLUORSPAR—FLUORITE

PHYSICAL PROPERTIES

Fluorite, or fluorspar as it is commonly called, is a non-metallic mineral, chemically a calcium fluoride, (CaF_2) consisting of calcium and fluorine in the proportions of 51.1 to 48.9. The mineral is oftentimes spoken of as "spar" but the term is very misleading as the average miner applies the same term to barite (heavy spar), calcite (calc spar, Iceland spar), fibrous gypsum (satin spar), ankerite (brown spar-pearl spar), dolomite, siderite, feldspar, quartz, etc.

Color.—Fluorspar may be almost any color from white, or colorless, and gray to deep red, deep green, and deep purple. In Colorado white, gray, brown, pale green, deep green, lavender, violet-blue, and deep purple fluorspar have been found.

Luster and Diaphaneity.—Its luster varies from vitreous in clear crystalline varieties, to dull and earthy in some of the granular varieties. Some deep purple varieties found near Evergreen had a sub-metallic luster. The mineral varies in its diaphaneity from transparent to almost opaque.

Crystal Form.—Fluorspar crystallizes in the isometric system and is often found in the form of cubical crystals, although the writer found numerous octahedrons encrusted with quartz in the Eagle mine near Bonanza, and in the Aspen mine at Silverton. Massive, crystalline and granular forms are common in Colorado.

Fracture and Cleavage.—The crystalline variety has a flat conchoidal fracture, the compact a splintery fracture, while optical fluorspar has a pronounced conchoidal fracture. It has a perfect octahedral cleavage shown by truncating the corners of a crystallized cube of fluorspar. The mineral is brittle and has a hardness of 4. This makes it slightly harder than calcite, but it cannot be scratched with a pin.

Streak.—When a mineral is drawn across a piece of unglazed porcelain producing a fine powder, the color of that powder is called its streak. Fluorspar gives a white streak.

Specific Gravity.—Fluorspar has a specific gravity of from 3.01 to 3.25, with an average of 3.13.

Occurrence.—The mineral occurs in beds or more commonly in veins or seams in granites, gneisses, volcanic rocks, arkose, slates, sandstones and limestones. In Colorado it is found mainly in granite rocks or volcanic rocks which are highly acidic.

Phosphorescence and Fluorescence.—One piece of fluorspar from St. Peters Dome exhibited phosphorescence under ordinary conditions, also a bluish fluorescence. This is undoubtedly due to the presence of yttrium and ytterbium which are known to exist in the associated minerals in the same vein.

Chemical Properties.—Fluorite may be readily distinguished by the following tests:

1. If heated in a closed tube it flies to pieces and glows.

2. Before the blowpipe, it fuses, coloring the flame red, and forms an enamel which gives an alkaline reaction when crushed and moistened on test paper.

3. It has a fusibility of 3 before the blowpipe, a small splintery fragment being readily fused.

4. It is slightly harder than calcite, since you can not scratch it with a common pin.

5. It does not effervesce with acids as do calcite and smithsonite. If fused in an open tube with salt of phosphorus it etches the glass.

6. By fusing a mixture of borax, acid sulphate of potassium, and fluorspar on a loop of platinum wire in the clear flame of the Bunsen gas lamp a green flash is seen which immediately changes to the yellow flame imparted by the sodium of the borax.

COLOR OF FLUORSPAR

The source of the color of fluorspar has not been definitely determined, although experiments tend to show that it is probably due to the presence of hydrocarbons rather than to metallic oxides.

Experiments by Wyroubloff[6] tend to show that the cause of the color and odor of fluorspar are the same, he having noted that in the violet-colored fluorspar from Welsendorf both color and odor were variable, and that the specimens with the strongest odor were also of the darkest color. In the course of his experiments he found that where there was no odor there were no hydrocarbons present, but that all specimens possessing an odor contained hydrocarbons. He also found that the quantities of metallic oxides present were totally inadequate to explain the color and were practically the same for several colors. As a result of his experiments on many different colors of fluorspar, he concluded that the coloring matters were various compounds of hydrogen and carbon, probably coming from bituminous limestone, and also that the phosphorescence on heating is due to the decomposition of the coloring matter.

W. S. Tangier Smith[7] suggests that the color may be due to the oxidation of the hydrocarbons, since they are found in colorless fluorspar, as well as in the colored varieties. He believes that the decrepitation of the fluorspar is closely connected with the amount of contained hydrocarbons, and noted that in the case of purple fluorspar occurring in vugs, the color where found was not uniformly distributed through the mineral, but was found in bands parallel to the surface of the vug. In some instances the bands completely encircled the cavity, passing from crystal to crystal and following all irregularities. These observations, he believes, strongly suggest, though they do not prove, that the purple fluorspar, at least in western Kentucky, is derived from fluorspar of other colors by the oxidation of the contained coloring matter.

Fohs[8] believes that the fluorspar occurred originally either colorless or brown, according to the amount and density of the contained hydrocarbons; that containing light hydrocarbons is white or colorless and that containing heavy ones is brown. He found that fluorite encased in unweathered barite is always colorless; that in softened barite and where calcite had been present and had been leached, is often purple. This he thinks is, in a manner, proof of the oxidation theory.

On account of the large number of localities visited and the limited time spent at each deposit, no special effort could be made

---

[6] Wyroubloff, M. G., Bull. Soc. Chem. de Paris, n. s., vol. 5, pp. 334-347, 1866.

[7] Smith, W. S. T., Lead, zinc, and fluorspar deposits of western Kentucky: U. S. Geol. Survey, Prof. Paper 36, p. 124.

[8] Fohs, F. J., Fluorspar deposits of Kentucky: Kentucky Geol. Survey, Bull. 9, p. 54, 1907.

to investigate the cause of the color of Colorado fluorspar. However, the following facts were noted during the investigations.

Nearly all fluorspar when struck or freshly broken gives off a peculiar odor characteristic of hydrocarbons. Contrary to the observations of W. S. Tangier Smith,[7] in the Kentucky fluorspar district, the purple fluorspar of Colorado seems to give off a stronger odor when broken than do the green, white, and colorless varieties. In the Jamestown districts the gray and white varieties, produced as a result of the weathering and bleaching of the violet-blue variety, undoubtedly give off a stronger odor than do the violet-blue fluorspars from which they are derived. The brown and purple variety, found in the Chancellor mine, seems to give off the strongest odor of all the fluorspars found in the state. This agrees somewhat with the findings of Smith, in that he believed that the brown fluorspar gave off the strongest odor.

With the exception of the lilac and purple-colored fluorspar, found in the replacement deposits of the Black Hawk mine at Rico, all the fluorspar deposits of Colorado are located within areas of pre-Cambrian granites and gneisses, or within areas of other highly acidic rocks of igneous origin.

The veins of the Jamestown district lie wholly within an area of pre-Cambrian granites and gneisses,—and although the greater part of the ores of the district are purple in color, there are two notable exceptions. The fluorspar found in the Emmett mine is deep purple in color, and the ore found in the veins on the hill above the Emmett is also purple. However, within a very few feet of these veins, another vein contains a considerable amount of colorless to pale green fluorspar, with no evidence of any purple fluorspar occurring in the vein. Some deep green fluorspar was noticed in a small opening, about 300 feet east of the Invincible mine. This occurrence was also peculiar, as all the fluorspar which has been found in that part of the district is purple in color.

In the deposit at Jefferson, the vein shows some deep purple fluorspar in the lower workings, whereas, in the upper workings on the same vein, the fluorspar occurs as a peculiar mixture of lilac and green-colored mineral.

The fluorspar vein in the Barstow mine at Red Mountain cuts an area of andesitic rocks, and where found at a depth of 1,040 feet is green. This point is below the zone of oxidization, but fluorspar found at or near the surface in other mines of the district is also green or colorless, as a result of bleaching. Large pieces of fluorspar from near the walls of the vein showed as high as 18 distinct color bands, varying from a light green to purple. These bands were parallel to the wall and did not appear to have any certain order of arrangement. Those bands occurring close to the wall were green, but were followed by violet bands which in turn were followed by bands of green, violet and blue.

The greatest variation in both color and method of deposition occurs in the Wagon Wheel Gap deposit. The various types of ore found in the deposit include, perhaps every color in which the mineral has been found. The fluorspar occurs in massive, crystalline, banded, and granular forms.

Not enough investigative work has been done on Colorado fluorspar deposits to determine either the cause or source of the coloring matter, but it can be seen from the facts noted that the source of the coloring matter can not be the same as that assumed for deposits in limestone regions, nor can the presence of purple ore be accounted for entirely by the theory of oxidation of contained hydrocarbons.

GENESIS OF FLUORSPAR DEPOSITS

Many different theories have been advanced in discussing the genesis of fluorspar deposits, but each deposit must be considered separately, as the derivation of the fluorine and the conditions affecting the deposition of the fluorspar were undoubtedly different in each deposit.

Clarke[9] discusses the origin of fluorspar as follows:

"Fluorite, although most abundant as a vein mineral and in sedimentary formations, is also found as a minor accessory in granite, gneiss, quartz porphyry, syenite, elaeolite syenite, and the crystalline schists. W. C. Brogger reports it both as an early separation in the augite syenites of Norway, and also as a contact mineral. It sometimes appears as a sublimation product or as the result of the action of fluoriferous gases upon other minerals, on volcanic lavas. It is also produced as a secondary mineral from the decomposition of various fluosilicates. It alters into calcite, being attacked by percolating waters containing calcium bicarbonate or alkaline carbonates. Crystallized calcium fluoride has been prepared by several processes, but they shed little light upon its presence in igneous rocks.

"Several other fluorides are found associated with granites or pegmatites—fluorine compounds, it must be observed, are rarely found in eruptive rocks. They are especially characteristic of the deep-seated or plutonic rocks, where the gaseous exhalations have been retained under pressure, and are commonly regarded as of pneumatolytic origin."

---

[9]Clarke, F. W., The data of geochemistry: U. S. Geol. Survey. Bull. 330, p. 274.

Throughout Colorado the main source of the fluorine appears to be the deep seated rocks of igneous origin. From this source, hydrofluoric acid or other fluorine compounds in which silica formed a part, were transported, with other elements in solution, by means of ascending thermal solutions. These solutions in ascending through various fissures, faults, and dikes came into contact with lime or with other solutions, and fluorspar was deposited.

Bischof[10] has described two important reactions in the chemistry of fluorspar. (1) Under the influence of solutions containing alkaline carbonates fluorspar alters to calcite. This process is believed to be more or less active in the oxidized zone where the absence of pyrite permits the waters to be of alkaline character. (2) Sodium fluoride in solution at ordinary temperatures is decomposed by calcium silicate with the formation of fluorspar.

According to Mendeleef some hydrocarbon compounds result from the addition of a halogen acid to a carbonate of the metal. Thus the combination, in certain proportions, of calcium carbonate ($CaCO_3$) and hydrofluoric acid (HF) results in the formation of fluorspar (CaF_2) and the hydrocarbon compound (CH_2O_3).[11] This explains a possible source of the hydrocarbons in fluorspar, and it may be that they are, in part, the source of the coloring compounds in the fluorspar.

According to Emmons and Larsen,[12] who have described the geology and hot springs of the Wagon Wheel Gap district, the fluorspar vein being developed by the American Fluorspar Mining Company, would if projected, bisect a deposit of travertine, which surrounds one of the thermal springs in the Valley of Goose Creek. A partial analysis of the travertine from this deposit was made by George Steiger of the United States Geological Survey, with the following results.[13]

[10]Bischof, G., Chemische Geologie, vol. 1, 2nd ed., Bonn. pp. 48 and 54, 1863.

[11]Fohs, F. J., Fluorspar deposits of Kentucky: Kentucky Geol. Survey, Bull. 9, p. 62, 1907.

[12]Emmons, W. H., and Larson, E. S., The hot springs and mineral deposits of Wagon Wheel Gap, Colorado: Econ. Geol., vol. 8, pp. 235-246, 1913.

[13]Burchard, Ernest F., Fluorspar at Wagon Wheel Gap, Colorado: U. S. Geol. Survey, Min. Res., pt. II, pp. 380-381, 1913.

Partial analysis of the travertine from Wagon Wheel Gap, Colorado, hot spring.

	Per Cent
Lead (Pb)	None
Zinc oxide (ZnO)	0.007
Barium oxide (BaO)	0.045
Fluorine (F)	0.22
Copper (Cu)	None

If these percentages were recalculated to a mineral basis, they would show 0.45 per cent of fluorspar (CaF_2).

Emmons and Larsen show that the hot springs and the fissure vein are undoubtedly connected, since the strike of the vein passes through one spring and close to the second. This would indicate that the fluorspar has been deposited by the hot waters which probably had their source at some depth. Analyses of the mineral waters of the springs, made in 1904, by the Chemistry Department of Colorado College, however, do not show the presence of fluorine in the water.

Penrose[14] in discussing the origin of fluorine in the Cripple Creek ore bodies says:

"The fluorite characteristic of the Cripple Creek ore bodies has a somewhat uncertain source. It is a well-known fact that fluorine compounds are common in the vapors from many modern volcanic vents, and fluorine minerals are found in many of the districts of past eruptive activity in the Rocky Mountains, though as associates of gold they are rare. On the other hand numerous fluorine minerals, such as fluorite, cryolite, tourmaline, and topaz, occur in the granite of this part of Colorado; so that there are two possible sources for the fluorine found in the Cripple Creek veins: First, the volcanic materials; and second, the granite. It is, of course, not impossible that the volcanic materials may have derived their fluorine from the surrounding granite, thus making the granite the ultimate source of this material. It has been shown by Mr. Cross that hydrofluoric, hydrochloric, and sulphuric acids might readily be evolved from the phonolitic magma during solidification, and he also suggests the granite and the vapors of indefinite source evolved from the fumaroles which were once probably abundant in the district, as other possible sources of the fluorine.

"The fluorine which now occurs in the veins is, so far as known, all in the form of fluoride of calcium, fluorite. It is not at all improbable that the fluorine originally came into the fissure in a volatile or soluble form such as hydrofluoric acid, or, more probably, as some of the hydrofluosilicates, or as soluble fluorides, and there encountered solutions

[14]Penrose, R. A. F., Mining geology of the Cripple Creek district, Colorado: U. S. Geol. Survey, 16th Ann. Rept., pt. II, pp. 126, 157-159.

which carried carbonate of lime derived from the decay of the eruptive rocks or from other sources. The natural result would be the formation of fluoride of lime."

Lindgren and Ransome[15] have proposed three possible sources from which the fluorine of the Cripple Creek ores may have been derived, but consider as the most probable the theory that the fluorine, together with the other volatile constituents, may have been given off by the phonolitic magmas on their consolidation at higher levels in the earth's crust. It is also pointed out that a remarkable connection exists between the phonolitic rocks and deposits containing fluorspar and gold not only at Cripple Creek, but also in the Black Hills, Judith Mountains, and Little Rocky Mountains.[16]

According to Purington[17] the fluorspar of the Telluride district originated as follows:

"The well-known connection of fluorine with volcanic action, and its occurrence as fluoride of calcium in granite fumaroles, make it still more probable that the ore of this region was of deep origin. No fluorite has, so far as known, been found in connection with the rocks now visible in the district, yet it has been found in greater or less amount in well-marked occurrences in four of the veins which lie wholly within the igneous rocks and near the probable center of eruption. Hydrofluoric acid, or other fluorine compounds in which silica forms a part, may, as suggested by Mr. Penrose for the Cripple Creek occurrences, have accompanied the other elements in solution, and, uniting with the lime, have deposited in the veins the fluorine in the form of fluoride of calcium, fluorite."

Spurr, Garrey and Ball,[18] in describing the ores of the Georgetown district, discuss the derivation of the fluorspar in the gold and silver deposits separately. In discussing the origin of fluorspar in the silver and lead deposits the following facts are pointed out:

"The sericitization of the wall rocks of the silver-bearing veins argues the presence of a little fluorine in the mineralizing waters, although not necessarily so much that fluorite should have crystallized from these waters. Elsewhere the evidence suggests that if the mineral was originally deposited by the primary mineralizing solutions it has since been reworked and deposited in a concentrated form by surface waters.

---

[15]Lindgren, W., and Ransome, F. L., Geology and gold deposits of the Cripple Creek district, Colorado: U. S. Geol. Survey, Prof. Paper 54, p. 219.

[16]Lindgren, W., Metasomatic processes in fissure-veins: Am. Inst. Min. Eng., Trans., vol. 30, p. 657, 1901.

[17]Purington, C. W., Preliminary report on the mining industries of the Telluride quadrangle, Colorado: U. S. Geol. Survey, 18th Ann. Rept., pt. III, p. 822.

[18]Spurr, J. E., Garrey, Geo. H., and Ball, S. H., Economic geology of the Georgetown quadrangle, Colorado: U. S. Geol. Survey Prof. Paper 63, p. 142. See also p. 153.

"The derivation of the fluorine in the original mineralizing solutions is also a matter open to doubt. The veins under discussion occur partly or wholly in granite. Granite is known to contain fluorine, which is present in mica, hornblende, and apatite, as well as in other minerals, and granitic rocks very commonly contain fluorite-bearing veins, in which the fluorite is either due to segregation from the granite or has been formed during the final process of consolidation."

In connection with the derivation of fluorspar in the auriferous deposits, it is pointed out that the fluorspar is evidently the product of the after action during the pneumatolytic period, when gases of magmatic origin rose along the channel followed by the intruded or extruded rock.

Fohs[19] in describing the genesis of the Kentucky-Illinois deposits says:

"Fluorspar consists of calcium and fluorine. The wall rocks form a ready source of calcium, but contained little or no fluorine. Igneous dikes of mica-peridotite, a dark green rock consisting of more than a dozen minerals, two of which, biotite and apatite, usually contain more or less fluorine, traverse the district. Upon analysis, this rock, none of which is very fresh, now shows very little fluorine content, yet it, together with the underlying mass from which it was given off, or the underlying mass alone, seems the most probable source of the fluorine. The compounds ultimately to form the deposits were transported by means of ascending thermal or heated solutions, coming as an aftermath of the eruption resulting in dikes."

USES OF FLUORSPAR

The uses of fluorspar depend on its chemical composition, fluxing properties, phosphorescence when heated, its optical properties, structure and color. By far the greatest part of the fluorspar used in the industries is utilized in the metallurgy of iron, steel, aluminum, manganese, gold, copper, lead, tin, nickel, and alloys of these metals. Next in importance is its use in the manufacture of various kinds of glass, sanitary and enamel ware, glazes and fireproof ware, and third its use in the chemical manufacturing industry.

OPTICAL FLUORSPAR

During the early spring of 1917 the search for optical fluorspar was encouraged by an appeal from the Director of the United States Geological Survey, to all fluorspar producers, asking that particular attention be given in their work of production to the finding of a transparent, colorless, or faintly-colored fluorspar,

[19]Fohs, F. Julius, Fluorspar deposits of Kentucky: Kentucky Geol. Survey, Bull. 9, p. 61, 1907.

suitable for the manufacture of lenses and prisms used in optical instruments.

At present the United States is dependent upon Japan and Switzerland for its supply of optical fluorspar, but since the war has cut off most of the foreign supply the United States must depend on its own deposits for the mineral. It has recently been reported that some absolutely clear fluorspar has been imported from Japan and has been valued at about $30.00 an ounce. This material has been used mainly in the manufacture of apochromatic lenses. Such lenses give a field of vision practically free from the color rings due to the breaking up of light rays.

A diligent effort was made during the examination of the Colorado fluorspar deposits to locate material that would be suitable for this purpose. Fluorspar from the Geo. Walker claims at Jamestown, from the Kentucky Belle, Rainbow and Rhodochrosite mines at Alma, and from the Barstow mine at Red Mountain was carefully examined but proved either too deeply colored or too badly fractured for optical purposes. The Barstow mine at Ouray appears to give the best promise of producing optical fluorspar, and with proper care, material well away from the metalliferous veins, and mined with the use of very little or no explosive might prove of optical quality.

The following description of the properties, uses and value of optical fluorite has been published by the Illinois State Geological Survey.[20]

"Properties, Uses, and Value of Optical Fluorite."

"Each transparent mineral not only bends or refracts rays of light in a definite and characteristic manner, but bends the colored components of the individual rays at slightly different angles—a property called dispersion. In addition to this, most minerals break light into two rays, each of which is both refracted and dispersed; only minerals that crystallize in very symmetrical forms, such as cubes or octahedrons, do not show this double refraction. Fluorite bends light very slightly (has a low index of refraction); disperses light faintly (that is, its refraction of red rays differs only a little from its refraction of yellow rays and so on); and normally displays no double refraction. These three properties place fluorite in a unique position among minerals and fit it for a highly specialized optical use which no other mineral or artificial substance can meet equally well. Only three or four other minerals have lower refraction than fluorite; but these are either colored or are not sufficiently transparent, and moreover show marked double refraction as a result of their crystallization. Hence fluorite stands alone.

[20]Pogue, Joseph E., Optical fluorite in southern Illinois: Bull. 38 (extract) pp. 1-7, 1918.

"Glass. of a special kind, is the dominant material used in all optical apparatus. By varying the chemical composition of the glass and the shape of the lenses and prisms made from it, the various optical effects desired are obtained. Owing to the reflection of light from surfaces and a breaking up or dispersion of light in passing through a substance, errors are introduced, and to neutralize or minimize these errors calls for the best efforts of technical art and scientific knowledge. It is here that optical fluorite finds its chief use. Due to its low refractive power and very weak color dispersion, this mineral is especially suitable for correcting the spherical and chromatic errors of lens-systems. The so-called apochromatic objective used with microscopes consists of a lens of fluorite placed between lenses of glass and represents the finest type of objective that optical art produces. There are two other classes of objectives, less fine and less costly, the achromat and the semiapochromat; fluorspar is used only in the second of these, which is a sort of compromise between the cruder achromat and the more nearly perfect apochromat. The less expensive semiapochromat could replace the apochromat in many instances, were optical fluorite more available; but at present the manufacturer is forced to conserve his meager supplies of fluorite for use in making the finer and more expensive apochromats. It therefore appears that a plentiful supply of optical fluorite would be of great benefit to the microscope industry, as thus far the output of optical systems containing fluorite has been limited simply by an insufficient supply of this material. The development of adequate sources of optical fluorite therefore becomes a matter of considerable importance, affecting ultimately through cheaper and more efficient microscopes the progress of scientific and medical research.

"Optical fluorite is also used in making prisms for spectrographs employed in ultra-violet work and for use in other optical apparatus in cases where great transparency to the ultra-violet and infra-red parts of the spectrum is required. It is likewise employed as part of the lens-system in telescopes to correct certain color effects. Specimens suitable for such highly specialized uses as those mentioned in this paragraph are difficult to obtain, because of the comparatively large size of pieces required; but the demand for such material is rather limited in an economic sense, though very insistent and important for the furtherance of investigational activities. While practically all fluorite possesses the optical qualifications noted above, the vast preponderance of material is too strongly colored or else too clouded with internal fissures and inclusions to transmit light unaffected by these undesirable influences. Moreover, some clear and colorless specimens otherwise suitable for optical use are found to show an anomalous double refraction, due probably to abnormal conditions during crystallization, which renders them unfit. These incidental, rather than inherent properties, therefore, become the controlling factors in determining the availability of material, and consequently determine the practical specifications which prospective material must meet.

"For optical use a specimen of fluorite must contain a portion at least one-fourth of an inch in diameter, free from flaws, and colorless or nearly so. Crystals, or pieces bounded more or less completely by plane surfaces, are more likely to qualify than irregular masses. As the surfaces of most crystals are dull, a corner of such a specimen should be broken off with a sharp blow so as to expose the interior. In doing this, it is desirable to rest the specimen on a wooden base and break off the corner along an incipient cleavage plane by means of a knife blade or chisel; such planes are usually present and may be located by moistening the specimen with kerosene. If the specimen looks promising, it is better to proceed no further, as fluorite is fragile and a misdirected blow will fill a clear piece with a net work of fractures. A peculiarity of fluorite of optical quality is its conchoidal (irregularly curved) fracture and the absence of a strong tendency to break into pieces bounded by smooth planes in the fashion of the ordinary mineral.

"As to color, material that is absolutely water-clear is of course the most desirable, and in fact is essential for highly specialized uses; but faint tints of green, yellow and purple do not in themselves render material altogether unsuited for optical use. Flaws must be lacking from the portion to be used, but flaws are present in the bulk of fluorite, due both to cracks (incipient cleavages) and to inclusions of bubbles or of visible impurities; accordingly the most detailed search is necessary to find pieces free from these objections. Moreover, careless handling, even jolts resulting from shipping, may develop flaws in clear material; hence the utmost care must be exercised in separating material of optical promise from its crude associations and in suitably packing such material.

"The anomalous double refraction shown by some specimens, particularly by symmetrical crystal groups known technically as 'twin crystals,' bars such material from optical use; but this property can be determined only by a microscope or other optical instrument at the eye of a trained observer. A clue to this condition is given in some cases by fine, parallel striations or rulings, marking a twinned condition of crystallization. In general, however, the clear specimens of southern Illinois fluorite already examined have been largely free from double refraction; hence for all practical purposes this test may be ignored in the field and left to the optical dealer to apply at his discretion.

"The value of optical fluorite and the demand for it cannot be expressed in definite figures, for the material is a specialized thing instead of a staple product. On the one hand, the demand will increase if optical fluorite can be produced at a figure sufficiently reasonable to warrant an enlarged utilization; whereas, on the other, an inflated price will destroy the opportunity for an increased demand. It must be remarked also that only a small portion, say 4 to 8 per cent on the average, of material classed as optical fluorite actually passes into the make-up of a lens-system, so much of the mass must be destroyed or discarded during manufacture. In other words, 25 pounds of good-looking, clear fluorite may produce no more than a single pound of finished lenses. Hence the value of the finished product comes only in part from the value of the raw fluorite entering into it; much of its value is introduced by the skillful work essential to its manufacture. These statements are to obviate the assumption that crude optical fluorite is of gem-value. In order to make the matter more specific, fluorite qualifying as optical in quality is worth a dollar or more a pound, while particularly large and fine specimens have an individual value of $10 and more apiece. These figures are rough approximations only, designed to give prospective producers a general idea of what their product may be expected to yield but not to be taken as quotations of market prices."

For the information of those who believe they might become producers of optical fluorspar the following names may serve as a list of possible purchasers:

Bausch and Lomb, Optical Co., Rochester, N. Y.

Spencer Lens Co., Buffalo, New York.

Bureau of Standards, Washington, D. C.

Wards National Science Establishment, Rochester, N. Y.

METALLURGY

In metallurgy, fluorspar has a wide application based mainly on its quality of rendering slags fusible at low heats. Other cheaper fluxes are used in the iron and smelter industry, but the superiority of fluorspar renders it almost indispensible in many operations.

As a result of experimentation it is seen that while the results obtained from using fluorspar are good, there is a limit beyond which the results do not increase as the quantity of fluorspar is increased. This is shown by an article in "The Foundry" for January, 1905, by N. W. Shed, and while it applies particularly to its use with foundry pig, it has also been found to be true in the manufacture of open hearth and Bessemer steel.

IRON AND STEEL

Since 80 per cent of the fluorspar output of the United States and all the imported fluorspar, is used as a flux in the manufacture of open hearth and Bessemer steel, it will be seen how important is its use in this industry alone. In the metallurgy of iron and steel it carries the silica, phosphorus and sulphur, three very detrimental elements, into the slag and effects a saving in fuel by permitting the charge to melt at a low temperature through its fluxing power. In the open hearth steel furnace fluorspar gives a more fluid slag in the basic process, allows of the use of a greater amount of cheap scrap, and eliminates part of the silica by volatilization, increasing the basic properties of the slag. The phosphorus content is lowered, partly through slagging and partly by volatilization.

In the Bessemer furnace the fluorspar fluxes the lime present making the slag effectively basic, while any phosphorus present tends to form calcium phosphate and later phosphorus fluoride, which passes off as a gas.

L. Goldmerstein[21] in the Iron Age describes a method of injecting small cartridges of manganese sesquifluoride into the molten metal. With the vaporizing of the fluorine of the compound and its union with the sulphur and phosphorus, for which it has a great affinity, the resultant compounds pass off as vapors. This should take place after the silica has been burned out, then on the injection of the cartridges the fluorine will unite with the impurities and the temperature of the mass will be raised.

Other artificial fluorides of both iron and manganese have been used in the Bessemer process with the same end in view, the creating of a more fluid slag, together with the removal of any sulphur, silicon, or phosphorus which might be present.

In the production of pig iron the use of fluorspar is limited by its high price. It is a very valuable flux, and when blown as a powder into the blast furnace through the nozzles, carries phosphorus into the slag and greatly reduces the fuel cost through its fluxing qualities. In cupola furnace work, if added to the limestone flux, it will carry part of the silica and phosphorus into the slag, and will form an alloy with the iron, producing a soft gray iron of greater malleability.[22] The slag is thin and the metal flows better and consequently sharper castings will result.

Fohs[23] states that in the electric furnace the addition of calcium fluoride forms volatile fluorides of silicon, sulphur, and phosphorus, and that the calcium forms a silicate slag.

OTHER METALLURGICAL USES

The presence of zinc sulphide with fluorspar is usually considered very detrimental in the smelting industry as it attacks the distilling vessels. However, the ordinary glazed distilling vessels are said to be greatly improved by a glaze baking consisting of sulphate of zinc and fluorspar in equal quantities.[24]

Fluorspar is used in minor quantities in the extraction of aluminum from bauxite.[25] In this process it is fused with bauxite and soda ash into a product resembling an artificial cryolite (sodium

[21]Goldmerstein, L., Prolonging the life of the bessemer process: Iron Age, Jan. 22, vol. 93, p. 250, 1914.

[22]Hill, R. C., The Foundry, May, 1915.

[23]Fohs, F. Julius, Kentucky fluorspar and its value to the iron and steel industries: Am. Inst. Min. Eng., Trans., vol. 40, p. 261, 1909.

[24]Fohs, F. Julius, Fluorine in lead and copper blast furnace slags: Kentucky Geol. Survey, Bull. 9, p. 174, 1907.

[25]Burchard, Ernest F., Our mineral supplies. Fluorspar: U. S. Geol. Survey, Bull. 666, p. 4, 1918.

aluminum fluoride) to which more bauxite is added; and from this mixture aluminum is extracted in the electric furnace. A process, as described by Hall,[26] consists in providing a bath of fused fluorides to which the aluminum is added and reduced by an electric current. The specific gravity of aluminum being greater than that of the bath, the metal sinks to the bottom and can be drawn off. Alloys of aluminum are made by placing a metal and alumina in a bath of fluorides, and the metal on melting will form a cathode, with which the aluminum unites as it is reduced.

Fluorspar is also used in the metallurgical treatment of ores of manganese, gold, copper, lead, silver, tin and nickel and in the production of alundum, a patented artificial corundum, used in making abrasive wheels, etc. This process is essentially one of fusing bauxite at extremely high temperatures, in an electric furnace.

In the smelting industry where limestone is usually used in the smelting of refractory ores, the use of fluorspar produces highly satisfactory results.

USE OF FLUORIDES IN WOOD PRESERVATION[27]

The use of sodium fluoride as a wood preservative was suggested by the use of certain fluorides, known to have antiseptic properties, in the prevention of wild yeast growths in mash. About 1906, tests on the impregnation of wood with solutions of sodium fluoride and zinc chloride were carried on for the first time; later tests with sodium fluoride were tried with apparently good results. The experiments show that the salt penetrates the wood very satisfactorily, that it is practically non-corrosive of iron or steel, and that the wood can be painted as usual. Tests show that the treatment has no apparent effect on the strength of the wood.

The cost of sodium fluoride for wood preservation should not be excessive. Enough tests have been made and enough data have been gathered by the Forest Products Laboratory to show its worth.

A report on impregnated panel tests and fire retardant paints[28] shows that panels treated with sodium fluoride, painted and exposed to the weather for 18 months stood the test remarkably well. The impregnation made them resistant to decay.

---

[26]Packard, R. L., Mineral resources of the United States. Aluminum: U. S. Geol. Survey, 16th Ann. Rept., pt. III, p. 540.

[27]Teesdale, C. H., Use of fluorides in wood preservation: vol. III, No. 4 and vol. 4, No. 1. Reprinted from Wood-Preserving.

[28]Gardner, Henry A., Report on impregnated panel tests and fire retardant paints: Paint Mfg. Assn. of the U. S., Bull. 51, Feb., 1916.

PLATING

Antimony fluoride is readily soluble in water, does not hydrolize and being entirely inorganic, does not decompose prejudicially or become altered during electrolysis. No other antimony salt possesses these properties which are so essential in making a plating bath.[29]

GLASS, ENAMELS, GLAZES

A considerable amount of fluorspar is now being used in the manufacture of common, plate, opaque and opalescent glass. In the manufacture of the last two, cryolite, a phosphate of lime, fluorspar, and feldspar have been used. But owing to the harmful effect of the high fluorine content of the cryolite, and the presence of phosphorus, the use of fluorspar and feldspar has increased. The ores of the Wagon Wheel Gap, Ouray, and Antelope Creek districts should be ideal for this purpose as they show few impurities and have no appreciable color. The color of the ores of the Jamestown district should not prevent their use in this industry since, on heating, they fuse and become white. The coloring matter evidently is not permanent and is of such small amount that it should not be injurious in the manufacture of glass.

Ground fluorspar mixed with a refractory substance is used as a flux in enamels. These enamels are used in the manufacture of bath tubs and sanitary ware, enamel ware, cooking utensils, clock and watch dials, and in the glazing of tile, brick, and terra-cotta.

HYDROFLUORIC ACID

Hydrofluoric acid is made in large cast iron vessels by decomposing the purest grades of fluorspar with sulphuric acid. The acid is used in chemical and metallurgical work, and as a cleaning agent for castings. The common formula used is one part of acid to 10 parts of water. This, if properly mixed, will remove the sand quickly and perfectly, the time required depending upon the amount of sand to be removed and the condition of the "pickle." An average of 10 to 15 minutes is required for the operation.

CONCRETE OR FLOOR HARDENER

Magnesium fluosilicate is used with zinc oxide, iron oxide, lithophone, silica and other pigments in the manufacture of con-

[29] Mathers, F. C., Means, K. S., Richard, B. F., Am. Electro-Chemical Soc., Trans., vol. 31, p. 293, May 5, 1917.

crete or floor hardeners, which are really paints. The magnesium fluosilicate seems to have the power of uniting with some element or elements in the concrete, producing a very hard, dense, and non-porous surface.

ORNAMENTAL FLUORSPAR

Fluorspar being but slightly more than half as hard as quartz is not ordinarily suitable for wear as jewelry. It takes a high polish closely resembling that of quartz, but it is easily scratched and is quite brittle. It readily splits along cleavage planes when being mounted. Through cutting and polishing the color is accentuated and many beautiful effects may be had which, if the stone were otherwise suitable, would make it a valuable gem.

The fact that the average Colorado Fluorspar fades on continuous exposure to light detracts from its gem value, whereas fluorspar from Derbyshire, England, is made into many ornaments. Vases are cut from particularly fine pieces. The color of this fluorspar does not fade on exposure.

A variety of fluorspar found at Amelia, Virginia, is both phosphorescent and fluorescent and is known as Chlorophane.[30]

The clear varieties of colored, transparent fluorspar are known as fake ruby, emerald, sapphire, and amethyst.

MISCELLANEOUS USES

Many other uses have been reported for the mineral. Among these may be mentioned its use in the making of cement, in the manufacture of carbon electrodes to increase their lighting efficiency and decrease cost, in the electrolytic refining of antimony, lead and copper and as a bond for the constituents of abrasive wheels.

The flue dust of cement works is calcined with fluorspar, and a second flue dust thus formed is collected and treated with water and lime or calcium sulphate to recover the fluorine and potassium compounds which it contains. This process has been patented and is now in use.

[30] Day, D. T., U. S. Geol. Survey, Min. Res., p. 960, 1904.

SUMMARY

Fluorspar for iron and steel manufacture should contain 85 per cent calcium fluoride, should not contain over 5 per cent of silica, and be free from sulphides and sulphates. Fluorspar used in the chemical industry should contain from 95 per cent to 98 per cent calcium fluoride.

During 1917 some fluorspar was shipped from Colorado for use in the chemical industry, but by far the greater amount produced was used in the manufacture of iron and steel.

CHAPTER IV

FLUORSPAR DEPOSITS OF COLORADO

BOULDER COUNTY

Fluorspar has been reported as occurring in the Allens Park district, in Antelope Park, and near Lyons, but as no definite information could be obtained regarding the exact location of the deposits they were not examined.

ELDORADO SPRINGS DISTRICT

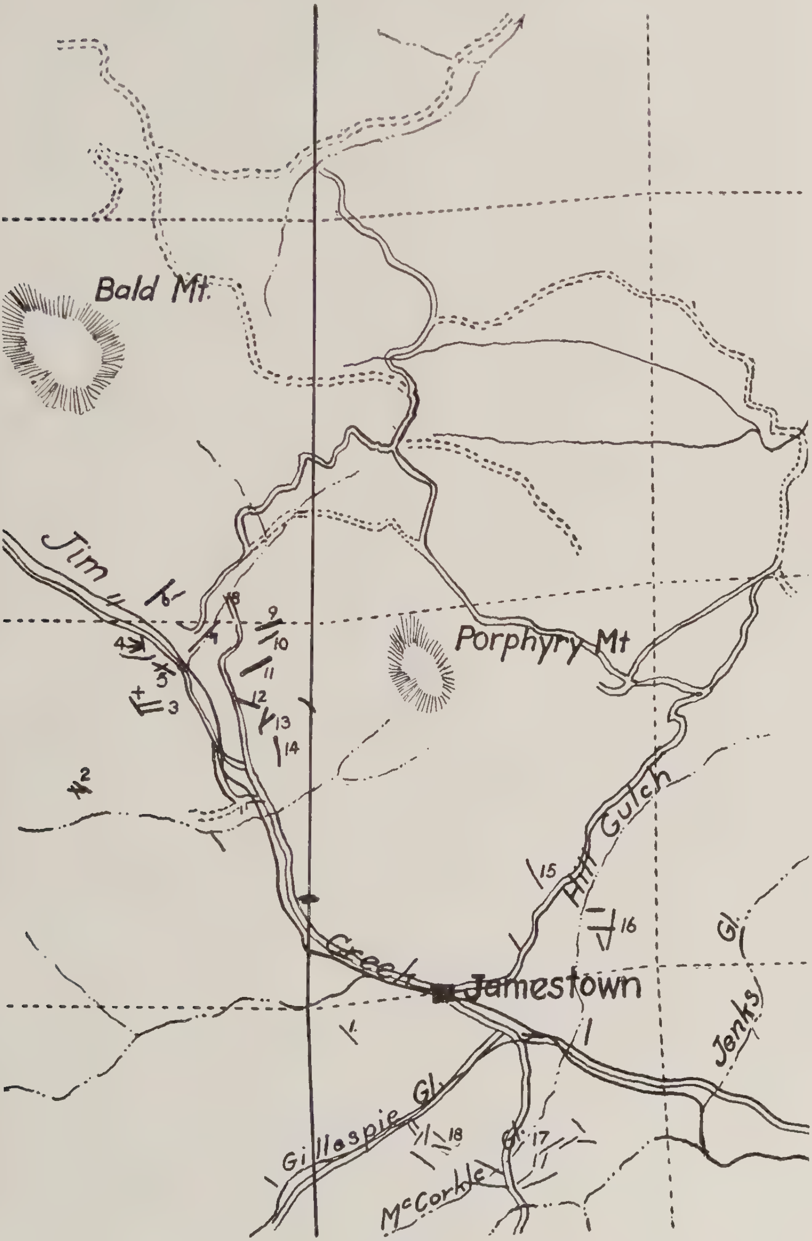
Some fluorspar was mined in 1917 about three miles west of Eldorado Springs. Samples of the ore containing 69 per cent of calcium fluoride were given the writer, but no examination was made of the property.

JAMESTOWN DISTRICT

The Jamestown mining district is located about 16 miles northwest of Boulder on Jim Creek, a branch of Lefthand Creek entering that stream from the north. It is reached by auto stage from Boulder over a splendid road following the base of the foothills and turning abruptly to the west as it continues up Lefthand and Jim creeks.

The town of Jamestown, commonly called Jimtown, is located on Jim Creek at an elevation of about 7,000 feet and is surrounded by mountains which reach an elevation of from 8,000 to 8,500 feet. The town was at one time scattered along the narrow valley for a distance of two miles, but had dwindled until in 1917 it had a population not exceeding 150 or 200 people, and only remnants remained to show the former size of the camp. Gold and silver mining had stopped, at least temporarily, through the closing of the Alice mine, at the extreme north end of the district. However, the increased demand for fluorspar was causing the opening of many old properties, and undeveloped deposits were being brought into production.

FLUORSPAR VEINS OF JAMESTOWN DISTRICT.
Topography by United States Geological Survey.
Contour interval—100 Feet. Scale—2 Inches = 1 Mile.



MINES.

1—Poorman
2—Silver Ledge
3—L. R. Evans
4—Geo. Walker
5—Emmett
6—Argo
7—Warren
8—Alice
9—Markt and Atkinson
10—Buchannan
11—Terry
12—Chancelor
13—Brown Spar
14—Invincible
15—L. Evans Lease
16—Buffalo Creek
17—Blue Jay Hill
18—Indian Point

The district is mainly one of granites and gneisses of pre-Cambrian age, intruded by numerous dikes of quartz, porphyry, and cut by many fluorspar and metalliferous veins. The main district extends northwest and southwest along Jim Creek for about two miles and although very irregular in shape reaches a maximum width of about one-half mile in both the northern and southern parts of the district. Jim Creek and its tributaries cut directly through the area, and have exposed numerous veins and dikes.

A large dike of quartz porphyry having a northeast-southwest trend cuts across Little Jim Creek, forming falls just north of the junction of Jim Creek and Little Jim Creek. On the east side of the district a mass of quartz porphyry forms the greater part of Porphyry Mountain and so far has proven barren of fluorspar veins. Other dikes of porphyry occur in the Emmett mine and on Indian Point where one dike with a northwest-southeast trend is exposed for a distance of 1,000 feet and is paralleled by a second dike which is exposed for about 400 feet. The district is divided by the porphyry dike crossing little Jim Creek, leaving a broad barren zone, with a mineralized area to the north and south.

FLUORSPAR VEINS

The granite of the northern half of the field is weathered to a less degree than that in the southern half. Both however are cut by many veins carrying fluorspar. These veins may be classed under one of the following heads:

1. Veins containing nothing but fluorspar.

2. Veins having fluorspar as the predominant mineral, and having quartz, decomposed granite, or clay formed by the decomposition of feldspar as gangue material.

3. Veins in which the principal mineral is fluorspar, but having galena, pyrite, chalcopyrite, chalcocite, bornite or some telluride mineral in addition.

4. Those formerly worked as metalliferous veins. Fluorspar was considered a gangue mineral in these veins, but they are now being worked for the fluorspar. These include the Argo, Alice, Chancelor, and Invincible mines, formerly working in either sulphide or telluride ores, but now operated for fluorspar.

The veins of the district occupy fissures in which movement has caused a greater or less amount of brecciation and mixing of the wall rock with the fluorspar of the veins. This is especially noticeable in the northern half of the district, where in the Warren, Argo, and Alice mines, angular pieces of wall rock are found enclosed in the vein matter. As to their direction the veins fall into two groups, those that have a strike northeast-southwest and those that have a northwest-southeast strike. Of forty veins examined twenty-five took the former direction and only fifteen the latter. Prominent veins are found in each group, but the larger number occur in the group having a northeast-southwest strike.

In width the veins vary from a few inches to a maximum of 17 feet, as shown in the Warren mine. This variation in width occurs both laterally and in depth, but an average width is from 2.5 to 5 feet. The Argo mine contains a great mass of ore in which width and direction are extremely hard to determine. This deposit can hardly be spoken of as a vein where it is opened, although, as a whole, it undoubtedly does take a definite course or direction.

COLOR OF ORE

In general, the fluorspar of the district is blue-violet in color, but almost colorless, and light green to deep purple ores are found. One characteristic of the ore is that on exposure to the light the purple color fades in a few months to pale purple, lavender and white. This fact makes prospecting rather difficult to the inexperienced, since the surface vein material becomes the same color as the country rock, and it is only through testing the hardness and looking for an occasional color that the ore can be distinguished. This bleaching often extends to considerable depth, and the fluorspar, which has the appearance of granules of quartz, is often mistaken for that mineral.

Some pale green to almost colorless, glassy-appearing fluorspar, was found on the hill above the Emmett mine and in an opening east of the Invincible mine on claims owned by George Walker of Jamestown. Material from both of these claims was examined with care but proved to be badly fractured. These veins contain the only known occurrence of nearly colorless fluorspar in the district, and appear to be the only ones which might yield optical fluorspar.

MARKET AND MINING

The ore is cobbed and all large pieces of wall rock are removed. The "gravel" ore is hauled 16 miles to Boulder, where it is either loaded on cars for the market, or concentrated prior to shipment. During the spring of 1918 only concentrates were shipped from

Boulder, as the Chesbro Company bought crude ore at the mines, hauled it to Boulder, concentrated it, and shipped it to available eastern markets. The opening of the Hoffnung or Lehman mill at Jamestown for the treatment of commercial ores, and the possible opening of the Wano mill for the same purpose should stimulate production. The crude ore can then be milled in the district and the concentrates hauled to the railroad at Boulder more cheaply than concentrates can be loaded on the car by the present method.

Fluorspar in the Jamestown district was being bought at the mine at prices averaging $7.00 per ton for 80 per cent ore. A premium of 20 cents per unit was paid for each per cent above that standard and a like penalty was imposed for each per cent below it. The minimum percentage of calcium fluoride was fixed at 70. A haulage charge of $3.00 per ton was deducted from this amount on settlement at the mill in Boulder.

Very little systematic fluorspar mining has been carried on in the district. Most of the work has been done for the purpose of getting out as large a tonnage as possible with the least expense to the operator, or has been done as assessment work. Most of the development consists of surface workings or short drifts usually not exceeding 200 feet in length. In these drifts the ore has, in many cases, been stoped so close to the surface that the property would soon cave. The workings are all shallow, the greatest depth reported having been reached in the sinking of a shaft to a depth of 112 feet, on Blue Jay Hill. A crosscut tunnel 300 feet long cuts this vein at a depth of over 100 feet, but the surface workings and shaft have caved. Most of the workings in the district cave when they stand idle, since the rock forming the walls is badly weathered and very little timbering is ever done.

The Alice mine, working at a depth of 400 feet, has a vein of fluorspar from four to five feet wide. This property and the Argo were previously worked as metalliferous mines but in the spring of 1918 the production of fluorspar was undertaken. The camp is now chiefly engaged in the production of fluorspar, and the output should increase rapidly as the demand increases.

Alice Mine.—The Alice mine had, up to the summer of 1917, been shipping a complex ore of galena, pyrite, chalcopyrite, chalcocite, tetrahedrite, tellurium and fluorspar, which ran well in gold, silver and copper. It is developed by a 400 foot shaft located 75 feet northeast of the main ore body. On four levels, crosscuts have been driven from the shaft to the ore body, which is developed by drifts, extending N. 20° W. and S. 20° E., ranging in length from 30 to 150 feet. A crosscut tunnel has been driven from the west, striking the vein at a depth of 40 feet, but is not connected with the shaft.

Vein Along Warren Vein Showing Outcrop of Fluorspar (xx), Alice Mine in Distance.

The fluorspar shows at the surface, is found in all levels, and lies to the west of the mineralized part of the vein. On the fourth level the fluorspar forms a vein from four to five feet wide in which there were a few pieces of granite wall rock and a small amount of finely disseminated pyrite. The wall rock is a coarse-grained granite or pegmatite, in which the feldspar minerals are somewhat weathered, but which stands well with very little timbering.

The property had shipped some little metalliferous ore in 1917, but in the spring of 1918 only a little fluorspar was being mined and shipped from the main vein, near the breast of the crosscut from the surface.

Mr. Mohr, one of the leasers, informed the writer that the property would undoubtedly ship some fluorspar that summer, and that a six-ton unsorted sample from the second level, ran 71.2 per cent calcium fluoride, but had a high silica content.

A particularly fine specimen of clear, glassy, uncolored fluorspar enclosing long slender crystals of native tellurium, and small rounded pieces of a dull black mineral which reacted for uranium and copper, was given the writer by Mr. Tom Mohr, who said it was found in one of the pockets of high grade metalliferous ore found in the mine. The fluorspar was too badly fractured and too small for use in the optical industry.

The ore is of a violet-blue color and undoubtedly extends below the 400 foot level. Although it is of no commercial value at present, because of its low fluorspar and high silica content, it could be brought up to market grade by concentration. The deposit is large and is properly equipped to handle a large tonnage, such as could be mined by stoping in the various drifts.

Argo Mine.—This property lies at the extreme northern end of the district. It was formerly worked as a metalliferous mine producing a large tonnage of galena, and cupriferous pyrite containing gold and silver. In the early days some carbonate of lead was found near the surface, and quite recently several hundred pounds of carbonate were found while prospecting for fluorspar in the large "glory hole," above the main tunnel.

The property is located in an area of porphyritic granite. The vein is branched and very irregular in width. The walls are poorly defined and the only way the strike of the vein can be determined is from the position of openings along its course. It is developed by a tunnel and two shafts, beside numerous drifts, upraises, and levels. The drifts have no uniform direction, but follow the fluorspar courses.

The fluorspar is a violet-blue mineral, in places stained a brownish color by iron oxide. When placed in the bins and allowed to stand, it bleaches rapidly to a light lavender color. The ore is soft and granular, the greater part appearing like "mill dirt" when placed in the bins. In places, the ore is high grade; in others, fragments and large pieces of wall rock lower the percentage of calcium fluoride and increase the silica content. It can be easily milled, and that appears to be the only means of getting rid of the fine pieces of wall rock scattered through the ore.

During April, 1918, the property was being operated under a leasing system and a considerable tonnage of fluorspar was being produced, but not enough work had been done to show the value or extent of the fluorspar deposits.

ARGO MINE.
1—Glory Hole. 2—Tunnel Portal

The opening of a vein to the west of the Argo had exposed some high grade ore. Work was being done in the gulch to the east on a vein running N. 47° E. Several sets of leasers were producing ore in the main workings of the Argo, and others had applied for leases.

Atkinson and Markt.—This vein running N. 81° E. is located 400 feet east of the Alice mine. Good ore is exposed for about 500 feet on the surface and the property is developed by a tunnel 60 feet long, entirely within the ore. The vein is about 40 feet wide, but very irregular, pinching and swelling through the length exposed. The ore is light violet-blue and is found in irregular-shaped masses throughout the vein. A shipping platform had been built and ore was being shipped to the mill in Boulder.

Blue Jay Hill.—On Blue Jay Hill at the south end of the district there is a series of fissure veins cutting the badly weathered granite. The main veins lie on the northwest side of the hill and parallel McCorkle Gulch. Several veins parallel Slaughter House Gulch, and others occur toward the east end of the hill. The ore found in the various veins on Blue Jay Hill is deep purple, hard, and quite solid.

The Blue Jay vein has been developed by open cuts, a shaft and a crosscut tunnel which cuts the vein at a depth of slightly over 100 feet. The shaft and surface workings are badly caved at present, but with a little cleaning up work, a good tonnage can be produced.

A large tonnage has been produced from the veins on Blue Jay Hill, and in the spring of 1918 ore was being shipped from four different openings.

Brown Spar.—The Brown Spar mine is located at the bottom of a small gulch several hundred feet to the northwest of the Invincible mine.

A tunnel cuts the vein at a depth of 25 feet, at which point a large, irregular body of ore 16 feet in width was taken out. There appears to be a branching of the veins at this point, one having a strike N. 68° E. and the other S. 53° E. The veins are vertical, and have side walls of granite. A shaft had formerly been sunk on the property, and an engine installed for hoisting the ore.

One set of leasers took out 2,000 tons of very good ore from this property in a short time. The property was under lease and was shipping ore to the mill in Boulder.

Buchannan.—The Buchannan is located about 500 feet southeast of the Alice mine. The vein has a strike N. 35° W., is nearly vertical, and is about 10 feet wide. The ore is violet-blue where it is not bleached, but where it is bleached it varies from gray to a light lavender. The ore does not fill the whole vein but forms irregular-shaped masses in the vein.

The property is developed by a crosscut tunnel to the vein, and by a small drift on the vein. An ore platform was built and other preparations for shipment had been made.

Buster.—The Buster Claim extends across the upper part of McCorkle Gulch, and the vein has been exposed for about 300 feet. It is nearly vertical and has a strike S. 64° E. and a dip of 83° SW.

McCORKLE GULCH.

1—Blue Jay Hill
2—McCorkle Gulch
3—Slaughter House Gulch
4—Indian Point
5—Southern Part of Jamestown

It was opened in 1911 by drifting on a 4-foot vein, but later a crosscut was driven cutting the vein at a depth of 30 feet. At this point the ore was 12 feet wide. A drift was driven 200 feet to the west along the vein and the surface was worked 100 feet to the east of the crosscut. In places the ore changes to a mixture of horn rock and fluorspar which is easily cobbed and sorted.

The fluorspar is deep violet-blue, and Mr. John Evans states that a shipment of 200 tons of sorted ran from 72 per cent to 78 per cent calcium fluoride and from 12 per cent to 16 per cent silica.

Chancelor.—This property was formerly worked for gold. A new crosscut tunnel has been driven several hundred feet above the main tunnel, and the ore has been stoped to the surface, a distance of 25 feet. The vein is nearly vertical and strikes S. 80° E. It occupies a fissure in the granite and is irregular in width both horizontally and vertically.

Violet-blue ore which has a decidedly brownish tinge is mined from stopes above the tunnel level and shipped to the mill in Boulder.

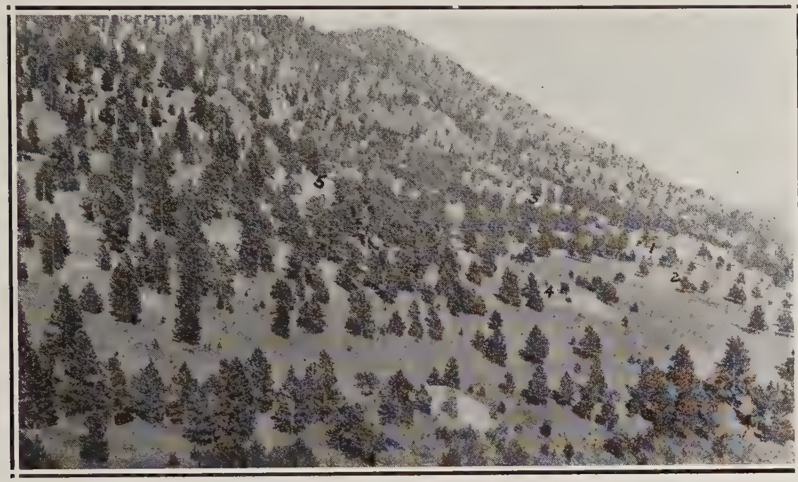
PORPHYRY MOUNTAIN FROM

6—Buchannan
7—Atkinson and Markt
8—Alice
9—Alice Cross Cut

Emmett.—The Emmett mine has been developed by a crosscut tunnel driven from a point on the west side of the road up Little Jim Creek, and by numerous drifts and stopes on the vein. In an upper drift the vein is vertical and strikes N. 60° W. until it comes in contact with a nearly vertical porphyry dike 14 feet wide. Here the vein turns and parallels the dike. On the other side of the dike the vein has the same direction N. 60° W., but where it comes in contact with the dike, it turns and parallels the dike to the east. It is a vertical fissure vein in granite. Some wall rock is enclosed in the ore, and in the upper drift near the porphyry dike great blocks or lenses of porphyry up to 10 feet in diameter are found in the vein.

The property has been a large producer of a purple-colored ore which is now shipped to the mill at Boulder.

Mrs. L. R. Evans's Claim.—This claim is located in an area of granite, and the veins occupy vertical fissures. The main vein has a strike S. 80° W. and is developed by an open cut 75 feet long. Beyond this the vein turns to N. 40° W. and is exposed in an open cut 40 feet long. A tunnel has been driven on a stringer of the main vein which it strikes in the open cut. Numerous other stringers, up to one foot in width, join the main vein from both walls. The main vein has a width of two feet in the end of the open cut. A dike of bronzite enclosing patches of deep purple fluorspar up to two inches in diameter, lies parallel to and 30 feet



MRS. L. R. EVANS' CLAIM.
1—Invincible 2—Brown Spar 3—Geo. Walker 4—Chancelor 5—Terry

north of that part of the vein which has a strike S. 80° W. Some good ore has been produced from this vein, but more work will have to be done before the extent of the deposit can be determined.

L. Evans's Lease.—L. Evans was one of three leasers on claims which are known as the Yellow Rose No. 1 and No. 2. They lie on the south side of Porphyry Mountain about 300 yards north of the Humboldt mine, and to the north of the road up Hill Gulch. The main vein is in granite and strikes N. 23° W. The main workings lie farthest north and consist of a 14-foot open cut to the vein and an open cut 20 feet long and 30 feet deep on the vein. The vein has a strike N. 23° W. and cuts the granite just south of Porphyry Mountain. Some very good ore was taken from this vein, and shipped to Pueblo.

Other veins are exposed to the south of this opening and some development work has been done. Some flakes of a lilac-colored mica found there proved to be muscovite, but the cause of the peculiar coloration could not be determined.

Invincible Mine.—The Invincible mine was formerly operated as a metalliferous mine, but during the past few years has been an intermittent producer of fluorspar. The property was not being operated early in 1917, although fluorspar was the principle mineral in a vein 12 feet wide, and was exposed in an open cut 50 feet long, 200 feet southeast of the shaft house.

The vein strikes N. 3° W. and although of varying width should prove a good producer, because of its persistency and its high calcium fluoride content. Although a shaft has been sunk on the property in close proximity to the vein, ore was being produced in 1918 through a tunnel and drift driven some distance below the shaft house.

Poorman Mine.—The Poorman mine which produced the first fluorspar mined in the Jamestown district and used for commercial purposes is located on the west side of Jim Creek on a hill overlooking Jamestown. The mine has not been operated for years, but ore found on the dump was a mixture of purple and brown fluorspar containing numerous fragments of the granite wall rock.

Silver Ledge Mine.—A 30-inch vein of fluorspar having a dip of 65° NE. and a strike of N. 72° W. has been exposed where it crosses the road, just east of the Silver Ledge mine. Development work in a tunnel shows that the vein varies greatly in width and contains a large number of granite fragments. It is said that other veins are known to exist in the mine but so far none have been developed for fluorspar. Further development work may result in the discovery of a better grade of fluorspar, but that now produced must be milled before it can be considered a commercial product.

Terry Claim.—The Terry claims consist of six or perhaps seven ore shoots in a vein 105 feet wide. The entire width of the vein, which strikes N. 30° E., contains fluorspar in irregular-shaped masses, the ore shoots being rather large and running in the same general direction through the vein.

The ore weathers to the same color as the vein material and country rock, so that it is hard for the inexperienced miner to determine just what is ore, without getting considerably below the surface. The unweathered ore is of a light violet-blue color.

The vein and ore shoots are exposed on the face, top, and sides of a large cliff, and the 400 or 500 tons of ore mined were taken from short tunnels in the foot of the cliff, and from gougings along its sides. Mr. E. R. Terry informed the writer that previous to 1917 the property had not been worked for four years.

George Walker Claims.—An opening on the hill directly north of Mrs. Evans's property shows the intersection of two fluorspar veins in the granite. One vein striking N. 85° W. has 4 feet of purple fluorspar, while the intersecting vein striking N. and S. contains four feet six inches of ore. Not enough work has been done to show the extent of the veins but from the character of the ore exposed in the opening further development should produce good results.

A number of veins have been opened on the hill, above and to the west and northwest of the Emmett mine. On the northeast side of the hill three veins radiate from a common center, striking S. 63° W., S. 84° W., and N. 43° W. All contain a very good grade of purple ore, and vary in width from two to three feet.

On the south side of the hill a vein striking S. 70° W. and turning N. 70° W. has been developed by a crosscut tunnel which strikes it just east of the angle. A drift has been driven a short distance to the east, and an open cut to the west. Very clean white to pale-green crystalline fluorspar was being mined from the vein in the open cut. The ore broke clean from the granite walls and very little wall rock was included.

Although the mineral was quite clear and nearly colorless it was too badly fractured to be of value as optical fluorspar. Care in mining might result in the finding of some material suitable for this purpose, as part of the fracturing is evidently the result of blasting in the mining of the ore.

Warren Mine.—The Warren mine is located on the northwest side of an east branch of Little Jim Creek between the Emmett and Alice mines. A crosscut tunnel 80 feet long follows a small stringer from the main vein. The vein strikes N. 49° E., lies between granite walls, and is developed by a drift 40 feet long. The ore has a maximum width of 17 feet. A shipment of 125 tons of ore from this vein contained 72 per cent of calcium fluoride. The grade of the ore was evidently lowered by the large amount of granite porphyry fragments it contained. Where the vein has a maximum width of 17 feet, over 100 tons has been mined by stoping, but no effort was being made to show either its extent or possibilities.

About 150 feet northeast of the main workings, a small tunnel 10 feet long, driven from the creek bottom, exposes a continuation of the main vein. Fragments of granite porphyry were scattered through the ore at this point. An analysis of a sample gave 62 per cent calcium fluoride and 31 per cent silica. The vein is well defined on the surface, and from indications the property could be made to produce a large tonnage with very little effort. The ore, however, will have to be milled, in order to raise the calcium fluoride content to the market standard.

VEINS NOT DESCRIBED

Many other veins of fluorspar have been exposed in the Jamestown district, but the writer has attempted to describe only those which are producing, or which show possibilities of becoming commercial producers under proper development. Some veins not described in detail are shown on the map of the Jamestown district, while many others not described or mapped were being discovered as a result of the renewed interest taken in the fluorspar industry.

CHAFFEE COUNTY

BADGER CREEK DISTRICT

Several fluorspar crystals of a light-purple color were received from the Badger Creek district east of Salida. No veins or deposits could be located in this area, although the writer made every effort to find the veins from which the specimens were supposed to have been taken.

MT. ANTERO DISTRICT

Early reports record the finding of occasional crystals in this district. Some kept as specimens in private collections would undoubtedly make excellent optical material as they are almost colorless, of good size, and apparently have very few if any fractures.

CLEAR CREEK COUNTY

Although fluorspar occurs as a gangue mineral in the gold and silver ores of the Georgetown and Idaho Springs districts, it is not plentiful. In the Mount McClellan and Argentine districts it is quite common and occurs as a green to purple-colored mineral in both the gold and silver ores. Numerous pieces of fluorspar were found on the dumps of mines in the district but very little information was obtainable as to its occurrences. The pieces found were badly fractured and when freshly mined were either light green or deep purple in color.

CUSTER COUNTY

ANTELOPE CREEK DISTRICT

A deposit of fluorspar occurs near one of the branches of Antelope Creek 16 miles southeast of West Cliff and 7 miles southeast of Rosita. The immediate area is one of pre-Cambrian granite and gneiss, and later eruptives which latter are not in close proximity to the vein. The fluorspar forms a shoot in a fissure vein cutting the granite and having a strike N. 41° E. and a dip of 80° to the southeast.

The property was badly caved, and an examination of an upraise and several drifts known to have been worked, was impossible. To the northeast of the main tunnel entrance, an open cut 110 feet long, and badly caved, showed a fluorspar shoot four feet wide in a vein which varied from four feet to fourteen feet in width. A tunnel, 100 feet long, driven along the vein from the north end of the open cut, was very badly caved, but showed decided irregularities in the width of the vein and the size of the ore shoot.

The following notes are from a description of the older workings by Burchard.[31] The property is developed by an adit and two drifts, 80 and 100 feet above the adit, all driven in the direction of the strike of the vein. There is one additional level 13 feet below the lower drift.

The adit, which is 200 feet long, was driven through barren vein material, and the ore shoot was reached about 50 feet higher, on a raise driven from the adit. The ore stoped in the levels was milled down the raise to the adit and then trammed to storage bins. The present surface workings are also connected with the lower adit, by means of a raise.

An examination of the workings of the lower level was impossible, so the writer's examination was confined to the surface workings. Some additional information was also obtained from former miners.

The fluorspar shoot varies from 20 inches to 4 feet in width, and averages 30 inches. It lies within the main vein which pinches and widens, and finally appears to end in some compact siliceous vein matter. On each side of the fluorspar is a band of brecciated siliceous matter cemented by fluorspar. This gets into the ore and makes sorting difficult.

[31]Burchard, Ernest F., U. S. Geol. Survey, Min. Res., pt. II, p. 612, 1908.

The fluorspar varies from light green to brown, which is the predominating color. It is finely fractured and at least part of the brown color is due to the infiltration of fine brown clay and iron oxides into the minute fractures which fill the ore. This brown color was noticeable even along the fine cleavages, and the thoroughly washed mineral when reduced to a fine powder would still show a slight brownish color, and would give a reaction for iron. Other pieces not so brown gave no reaction for iron and changed to a white color when heated. The ore appears to be free from siliceous matter except along the side walls. One small pile of ore on the dump was very free from foreign rock matter, and showed what could be done by careful sorting. Several pieces of violet-blue spar were found, but no clear transparent material was noticed.

The writer was informed by a former miner that the ore was always above the standard set by the Colorado Fuel and Iron Company at Pueblo. But it required exceptional care in sorting the ore to keep it above 80 per cent in calcium fluoride, because the siliceous rock of the sides of the ore shoot became mixed with the ore in mining.

The property has been idle for several years, and was last worked by J. C. Steiner and D. D. Moninger who organized the Jocomo Mining Company to develop the property, and it is now known by that name. Over 1,000 tons of fluorspar of very good grade was mined, hand sorted, and hauled 16 miles to the railroad at West Cliff, over a good road, the first 7 miles of which is quite hilly.

A considerable expense would be entailed in the opening up of the property, because of its badly caved condition, but if after opening it up a thorough examination still showed the existence of proper ore bodies, the ore could be jigged or milled nearby. A stream which might furnish enough water for small milling purposes flows within 100 yards of the property. This would enable the operator to get a product of higher grade and low in silica.

DOLORES COUNTY

RICO DISTRICT

Fluorspar is not a common mineral in the ores of the Rico district but is found sparingly as a gangue mineral in several of the mines. In the replacement deposits of the Black Hawk mine it occurs as a colorless to light purple gangue mineral associated with pyrite, chalcopyrite, sphalerite and galena. Ransome[32] reports it occurring as a gangue mineral in the large pay shoot outcropping at the back of the bunk houses of the Black Hawk mine but it is not now found in that ore shoot. Some small pieces were found on the dump of the Duncan mine where it occurs as a gangue mineral in a pyrite-chalcopyrite ore. The fragments were of a pale lilac to light green color, and very much fractured.

DOUGLAS COUNTY

DEVILS HEAD DISTRICT

Crystals of both green and purple fluorspar are found in the area of pre-Cambrian rocks around Devils Head. Some beautifully colored crystals up to one and one-half inches in diameter have been found, but at present crystals are found only occasionally and these are too deeply colored to be of value for optical purposes.

EL PASO COUNTY

PIKES PEAK DISTRICT

Crystals of fluorspar have been found in this district but no veins of the mineral are known to exist.

CASCADE AND UTE PASS DISTRICTS

Fluorspar has been found at Cascade and in several tunnels of the Colorado Midland Railroad in Ute Pass. No outcrops of veins however were found.

ST. PETERS DOME DISTRICT

This area is usually spoken of as the St. Peters Dome district but should really be divided into the Duffields and the Cather Springs districts.

Duffields Area.—About one-third mile east of Duffields the railroad cuts through a vein of fluorspar, which stands exposed high on both sides of the track. The vein is developed by a tunnel 85 feet long which starts in a gulch to the north of the tracks, and has been driven in the direction of the tracks.

A second outcrop developed by an open cut 35 feet long lies to the south of the tracks on the opposite side of the hill.

[32]Ransome, F. L., Economic geology of the Rico quadrangle, Colorado: U. S. Geol. Survey, Rico Folio 130, p. 15.

The vein developed by the tunnel strikes S. 10° E. and lies between walls of granite. It is very irregular in width both laterally and vertically and in places breaks up into a number of seams from 3 to 6 inches in width between which is a siliceous material, made up mainly of orthoclase and quartz. The vein varies in width from 30 inches to 10 feet and averages 5 feet. The mineral is deep purple and green and is badly fractured. The seams are filled with a fine brown clay material. The mineral also seems to be somewhat laminated, as if it had been pressed out through movement, but no faulting or other evidence of movement was observed.

The vein shows the same characteristics in the cut on the railroad tracks, where it reaches a width of 15 feet. It can be traced 2,000 feet to the north and is exposed in several old shafts where it is associated with galena and sphalerite. This district has been prospected for gold and the shafts were sunk on this supposed metalliferous vein. The tunnel is badly caved and will require a considerable expenditure to open it up. It was first worked for fluorspar in 1910-1911 when a small tonnage was hauled on a skid to Duffields for loading. The ore was cobbed and sorted. During later development some of the finer material was screened before being shipped.

The opening to the south of the tracks is either the same vein or a branch which has a trend S. 30° W. An open cut, now quite filled, had been made and the ore from a 3 foot vein was thrown on the side of the cut, where it still remains.

The fluorspar in this cut is lighter in color than that in the tunnel and contains a higher percentage of silica. No effort has been made to mine this ore during the past 8 years.

Cather Springs Area.—During June, 1917, a railroad spur was put in at Cather Springs and a road built along the side of the mountain, to a vein of fluorspar then being opened up one-half mile south of the railroad and known as the Cather Springs deposit.

A fissure vein two and one-half to four and one-half feet wide in the granite strikes S. 20° E., dips 80° N. 45° E., and is exposed along the hill side for 2,000 feet. It is developed by two shafts and a tunnel, used in the former development of the vein as a gold silver property. A large amount of quartz is found along numerous small water courses in the vein although some solid fluorspar of good grade occurs next the walls. The mineral is generally green but when it is bleached to a gray color it is almost impossible for the inexperienced to distinguish it from quartz and siliceous vein matter.

An effort was being made to sort over the dump from an old shaft 100 feet deep, and considerable good ore was being found and loaded on a car at the spur. The ore will not be hard to mine, but extreme care must be taken in the sorting, or the silica content will be excessive.

As no freight trains were being run over the railroad from Cripple Creek to Colorado Springs, cars had to be "set in" by a switch engine from Colorado Springs. A switching charge is made for this, which, added to the cost of mining, reduces the margin of profit considerably.

GILPIN COUNTY

No commercial veins of fluorspar are known to exist in this county. However, the mineral is found in a number of mines, where it occurs as gangue in both pyritic and telluride ores.

Bastin and Hill[33] in describing the ore deposits of the district show that where the ore is a replacement of the wall rock, the gangue minerals are the wall rock minerals or their alteration products, notably sericite. Where the ore is a filling of open spaces, the predominant gangue mineral is quartz. Siderite is a subordinate gangue mineral in certain deposits, and fluorite an abundant mineral in others. Fluorite is a characteristic gangue mineral in certain of the rich telluride ores, but it occurs also in certain pyritic ores, particularly those containing enargite. This association is not always the rule as is shown by its occurrence and absence in both types of veins. The fluorspar occurs as a green or purple or more rarely a colorless mineral in the pyritic veins, and is always a subordinate vein material. No optical fluorspar was found in the district.

Fluorspar is known to occur in the following mines: The War Dance, Treasure Vault, Chase, Togo, Silver Dollar-Hampton, Powers, Iroquois, Anchor, Hazeltine, Hill-Bunk House.

GUNNISON COUNTY

CRYSTAL DISTRICT

Fluorspar is found as a gangue mineral in the lead ores of the Lead King mine. Several colorless crystals up to one and one-half

[33]Bastin, Edson S., and Hill, James M., General features of the economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colorado: U. S. Geol. Survey, Prof. Paper 94, pp. 105. 106, 114, 134.

inches in diameter have been seen in private collections and are said to have come from this property, but no material of value was found in visiting the district.

HINSDALE COUNTY

Fluorspar has been found as a gangue mineral in the ores of the Hidden Treasure mine which is located within an area of andesitic rocks of the Picayune Volcanic group.[34] Some small pieces of fluorspar which were found on the dump of the mine, were of a pale green color, but too badly fractured for optical purposes.

JEFFERSON COUNTY

EVERGREEN DISTRICT

The area near Evergreen is one of pre-Cambrian granite and gneiss cut by fissure veins and dikes of pegmatite.

To the south and southwest of Evergreen the fissure veins contain mainly fluorspar, associated with lead, zinc, and copper minerals which occur in minor quantities only. Certain other veins which appear to run high in fluorspar, with small amounts of metallic sulphides, have been developed, but the fluorspar is only local and the vein filling changes to quartz. Pegmatite dikes often contain small amounts of fluorspar and metallic minerals, but these minerals are only of minor importance in the dikes.

A well-defined vein of fluorspar having a strike N. 35° E. crosses Cub Creek and has been opened in the workings of the Augusta mine one and a quarter miles south of Evergreen. The same vein outcrops on the northwest side of Cub Creek about three-quarters of a mile southwest of Evergreen, and again on the Brookvale road one-quarter of a mile west of the Evergreen-Bergen Park Road . This is locally known as the Augusta vein and can also be traced several miles to the south, through openings along its course.

A second vein known as the Bull Hill claim is located on the south side of Cub Creek one and three-quarters miles south and west of Evergreen. It can be traced for over a quarter of a mile. It is covered at one end by surface material, and ends in a mass of quartz at the other.

Augusta Mine and Vein.—This property was formerly worked for metalliferous ores and is developed by a crosscut tunnel 270 feet

[34] Bancroft, Howland and Irving, John D., Geology and ore deposits near Lake City, Colorado: U. S. Geol. Survey, Bull. 478, p. 46, 1911.

long which cuts the first and larger of the two veins at a depth of 95 feet, and a distance of 190 feet from the portal. The crosscut has been driven 80 feet beyond this point, but has not encountered the second vein. At the junction of the crosscut and the vein, a winze had been sunk 26 feet. Drifts have been driven to the south 50 feet, and to the north 20 feet. Practically the entire ground above the tunnel level has been stoped up to connect with old surface cuts.

The vein is of the fissure type, strikes N. 35° W. and dips to the southwest, having a horizontal displacement of 14 feet in each 100 feet of depth. The wall rock is a hornblende-biotite gneiss which in places changes to a granite. Movement has squeezed out the hornblende and biotite of the gneissoid walls which in places show considerable slickensiding. The vein varies in thickness from 1 to 5 feet, and averages 2 feet. The light purple and green fluorspar is sometimes replaced by kidneys of zinc, lead and copper ore weighing up to 50 pounds. In the end of the north drift the fluorspar crumbles rapidly on being broken, and in mining becomes mixed with quartz and orthoclase which form numerous stringers in the vein.

The fluorspar was formerly mined by surface workings and carted to Black Hawk for use as a flux. These workings are now badly caved, and the fluorspar, where it is found in place, appears very quartzy. On close examination this appearance is seen to be due to the clear colorless character of the mineral, the result of its bleaching in the sun, and to the presence of perfect cleavage surfaces and conchoidal fractures. No optical fluorspar was found, as the clear mineral was full of incipient fractures.

A second vein lies about 100 feet to the east and parallels the first but is narrow and cannot be profiitably worked under present conditions. The other openings to the northwest of the Augusta mine expose a body of fluorspar from 2 to 4 feet wide, with a dip to the southwest. The ore is of a fair grade, but is mixed with more or less quartz. Over 1,000 tons have been hauled from the property to the railroad at Morrison, a distance of 12 miles. From there it was shipped to Pueblo, where the greater part of the ore has been marketed. The property was idle during the fall of 1917 and spring of 1918.

Milling cannot be undertaken at Evergreen, as the City of Denver will not permit the dumping of tailings into either Cub Creek or Bear Creek.

Bull Hill Claim.—This property is located one and one-half miles south of Evergreen and is developed by a shaft, 105 feet deep, but now filled to 50 feet from the surface. Several drifts not exceeding 13 feet in length follow the vein to the northwest, and one extends 14 feet to the southeast. The vein strikes S. 45° E., dips 80° to the southwest and varies in width from 2 to 4 feet. The ore is of an extremely deep purple color and in places is quite honey-combed, through the leaching out of some other mineral. The holes thus formed were irregular in shape and the walls were so etched, that the mineral removed could not be determined.

The vein changes into a pure white quartz both to the northwest and southeast and unless the fluorspar persists in depth the deposit will not prove extensive.

Ore for an experimental mill run was being taken out by the operator, H. L. Littell, and was to be hauled by truck to Denver for milling. To avoid any unnecessary expense, especially in the purchase of hoisting machinery, the ore was being hoisted by means of a rope attached to an automobile and run over a pulley to the bucket.

BUFFALO DISTRICT

A small vein of fluorspar is found on the north side of the hill 300 yards west of the school house at Buffalo, and a second vein is located on a hillside 200 yards south of the Buffalo-Pine road three-quarters of a mile west of Buffalo.

The fluorspar found near Buffalo occurs as a small seam 2 to 3 inches wide, in a fissure vein which cuts an area of hornblende-biotite granite. The vein which is about 14 inches wide has a strike S. 35° E. and a dip of 80° N. 55° E. and is filled mainly with a dark brown siliceous vein matter. Fluorspar of a dark purple color is found near the center of the vein matter, which in places is broken up into alternate bands of quartz and fluorspar. The vein outcrops for a distance of 225 feet along the hillside and is developed by two tunnels one 80 feet long and the other 35 feet. Both tunnels were driven in 1897 and 1898, as the result of finding some galena mixed with the fluorspar of the vein.

The second vein is 14 inches wide and has a trend S. 17° E., in an area of granite. The fluorspar occurs as a gangue mineral associated with galena, pyrite, and barite, and is rather prominent in the vein. The property which was formerly worked for gold and silver is developed by two openings on the vein—the first a shaft 35 feet deep and the second an open cut 6 feet deep. The property has not been worked since 1898, and as a result is now badly caved.

The fluorspar is deep purple in color, very badly fractured, corroded, and covered with a brown iron oxide.

BERGEN PARK AND CLEAR CREEK CANYON DISTRICTS

Samples of fluorspar, said to come from the district between Bergen Park and Clear Creek Canyon have been handed the writer on two occasions, but a close search of the district failed to discover any outcrops of veins carrying fluorspar. The sample may however be from a very small area which was overlooked in the search.

LAKE COUNTY

Emmons[35] in describing the ore deposits of the Sweet Home mine at Leadville says: "This mine is interesting from the varieties of mineral species thus far obtained from it. Among these are cuprite, fluorite(pink and blue), jamesonite, melanterite, rhodochrosite, and zinkenite." Fluorspar undoubtedly occurs in other mines in the district, but these occurrences are local and of so little importance, that its presence is almost unnoticed. No investigative work was done in this district.

LA PLATA COUNTY

In the mines of the La Plata Mining district fluorspar and a number of other minerals such as quartz, calcite, rhodochrosite, dolomite, asbestos, garnet, chlorite, and kaolinite are found as gangue minerals in the ores.[36] No fluorspar of value, either for fluxing or for optical purposes, was located in the district, only small pieces being found on the dumps of several of the mines.

MINERAL COUNTY

WAGON WHEEL GAP DISTRICT

An extremely large deposit of fluorspar has been developed by the American Fluorspar Mining Company one and a quarter miles south of the Wagon Wheel Gap station on the Denver & Rio Grande R. R. This deposit is located on the east side of Goose Creek at a

[35]Emmons, S. F., Geology and mining industry of Leadville, Colorado: U. S. Geol. Survey, Mon. 12, p. 527.

[36]Purington, C. W., Economic geology of the La Plata quadrangle, Colorado: U. S. Geol. Survey, La Plata Folio 60, p. 13.

point directly opposite the Mineral Hot Springs, a resort well-known for its mineral waters.

The vein was located in the belief that it was an extension of the Amethyst vein at Creede. Both veins strike northwest and southeast and cut through country rock of the same type.[37] On account of the resemblance of the amethyst and purple fluorspar to the radiating amethyst-quartz crystals found in the Amethyst vein at Creede, no one appears to have known that it was fluorspar. As the fluorspar vein carries but little gold and silver but little attention was given to it. In 1911 the mineral was recognized by S. B. Collins, the president and general manager of the American Fluorspar Mining Company, and by 1913 development had progressed to the extent that 5,000 tons were shipped to Pueblo. During 1914 the mine was idle but reopened in 1915, and has been worked intermittently to the present time.

GEOLOGY

The vein which is exposed on the steep hillside to the east of Goose Creek, may be traced about 2,500 feet to the east where it appears to end in a small gulch or flat. The vein lies entirely within an area of Tertiary volcanic rocks consisting of beds of rhyolite tuff, with some quartz latite and andesite. On the top of the hill, and in close proximity to the vein, reddish rhyolite and quartz latite predominate, but in the vicinity of the present workings on the hillside, andesite appears as the predominant rock and forms the walls of the vein.

DEVELOPMENT

The property is developed by two tunnels, and several small shafts and open cuts have been dug in prospecting the vein at the extreme eastern end of the property. The lower tunnel has been driven over 600 feet along the vein from a point near the base of the hill. The main workings on the hill include several drifts, stopes and upraises all driven from a tunnel located about 600 feet above the lower tunnel, and about 700 feet above the stream. An aerial tram, with two supporting towers and operated by gravity, connects the upper workings with ore bins of 300 tons' capacity located at the foot of the hill, near Goose Creek. At the upper end of the tram a terminal with "grizzly," sorting plats, and bins of 75 tons' storage capacity provide for the production.

[37]Lunt, Horace F., A fluorspar mine in Colorado: Min. and Sci. Press, pp. 925-926, Dec. 18, 1915.

Prior to the summer of 1917 the ore was hauled by team to Wagon Wheel Gap and loaded on cars at a spur one-quarter mile above the station. In July, 1917, a tram track was laid along the base of the mountain on the east side of Goose Creek and the Rio

Colorado Fluorspar Company, Wagon Wheel Gap. Aerial Tram and Upper Terminal from Point on Vein above Present Workings.

Grande River, to a point where it crossed the river on an old wagon bridge just east of the station. Here the tracks were elevated so that the ore could be dumped directly into the railroad cars. The grade was such that a mule could pull a number of cars, and as the track had numerous switches, several trains could be run each way at once, and a large tonnage loaded on the railroad cars.

FLUORSPAR VEINS

The vein is of the fissure type and is very irregular in width both vertically and horizontally. In places it has a maximum width of 14 feet, but the average as seen in the main workings is about 4 feet. Numerous branches, offshoots of the main vein, occur in the upper workings. On the north side of the hill paralleling the vein, a great number of fluorspar boulders have been found covered with wash. The vein is persistent in its strike, which varies from N. 80° E. to due E., and throughout has a dip of 70° to 80° southward. That part of the vein at the extreme east end of the property has the same strike and dip. The vein at the east endline near

Colorado Fluorspar Company, Wagon Wheel Gap. Main Tunnel

where it disappears is about two to two and one-half feet wide. The wall rock of the vein, a rhyolite tuff, seems to be decomposed less than in the main workings, but this condition may change with depth.

In the lower tunnel the wall rock is much altered in many places and the vein varies in width, but apparently is not nearly as strong, the average width of the fluorspar being not over 20 inches.

FLUORSPAR

The ore in the main workings is mainly fluorspar, barite, creedite, fragments of country rock, and gouge. Very little barite is found below 25 feet and none below 200 feet. The fluorspar occurs in a number of forms, but (a) mainly as a white, sugary or granular fluorspar forming solid masses across the whole width of the vein; (b) as yellow-green, green, blue-green, yellow, brown, lilac, violet, blue, and purple fluorspar, either as an encrusting mineral on fragments of andesitic wall rock; (c) as banded material on the side walls of the vein; (d) as a massive vein-filling mineral; (e) as a crystalline mineral facing inward along water courses; (f) as a banded material with an apparent botryoidal form; (g) as typical concentric lenses in the ore body; (h) as an aggregate mass with crystalline barite. Along water courses the mineral may be entirely honeycombed, whether it be crystalline, granular or massive. Radiating crystals of fluorspar, which vary in color from the inside out, but usually terminate as a purple crystal, are quite numerous. The vein is composed of such a variety of types, colors and forms of fluorspar that their derivation and extent could only be determined by a prolonged study of the deposit.

Colorado Fluorspar Company, Wagon Wheel Gap. Upper Terminal and Ore House.

At the time of the writer's visit, ore of each type just described was being produced from various places in the mine. One large upraise which had reached the surface was driven in a fluorite-barite ore body from 12 to 14 feet in width, in which the barite occurred as perfect crystals among radiating crystals of fluorspar. This condition prevailed to a depth of 25 feet, below which the amount of barite became negligible. Fluorspar showing a banded coloration was common. The bands were either parallel or concentric, depending on the type of ore encountered.

The wall rock is badly weathered, but one wall is almost always good. The water courses which are numerous near the surface are continuous and are found even in the lower tunnel. The wall rock contains some finely disseminated pyrite, which is altered in some cases to limonite and hematite. In the upper workings a new mineral has been found which has been described by Larsen and Wells[38] under the name Creedite. Some of this mineral was found on the dump of the upper workings.

The fluorspar, where exposed at the east end of the vein, occurs as purple or amethyst-colored radiating crystals, in some cases covered with a thin film of silica, and in many other cases covered with a coating of brown iron oxide. In the lower tunnel the wall rock is badly weathered and at one place where it passes through a body of soft, highly altered country rock, a number of white balls of varying diameter were found. These have been described by Larsen and Wells as Gearksutite, which like Creedite is a fluorine mineral.

PRODUCTION

The ore is put over a "grizzly" after which the larger pieces are sorted, cobbed, thrown with the fines and carried by tram from the upper to the lower terminal, for storage until hauled to the railroad. Only the large pieces of barite, wall rock, and gangue are thrown out in this sorting. The ore is easily kept above 80 per cent in calcium fluoride. With extreme care and a choice of ore, the grade can be run up to 98 per cent calcium fluoride. Such ore may be shipped to eastern markets for chemical work.

Ore from this deposit has been shipped to both coasts, and while some is being shipped to the Colorado Fuel & Iron Company at Pueblo, a large quantity goes to eastern markets. No data were obtainable as to the total production, but in March of 1917, 1,440 tons were shipped. It is expected that this output will be doubled as soon as the new tram can be placed in operation.

The deposit is exceedingly interesting from a geological, mineralogical, and production standpoint, and should be thoroughly investigated at some future time.

[38]Larsen, Esper S., and Wells, Roger C., Some minerals from the fluorite-barite vein near Wagon Wheel Gap, Colorado: Nat'l Acad. Sci., vol. 2, p. 360, July, 1916.

The published analyses of the mineral waters do not show the presence of fluorine, but it may be doubted whether they have been carefully examined for this element. It would seem probable that a more or less direct relationship may have existed between the thermal springs and the origin of the fluorspar veins.

MONTROSE COUNTY

A small deposit of fluorspar has been found 14 miles northeast of Montrose, along the south side of the Gunnison River, on Vernal Mesa. The property lies about three or four miles to the northwest of the point where the Government road reaches the top of Gunnison Canyon. From that point a road extends one and one-half miles toward the deposit, and beyond this there is a trail.

The area is one of pre-Cambrian granites and gneisses which show a large amount of folding. The vein cuts through a granite-gneiss complex and is easily traced for some distance down the walls of the canyon. The fluorspar occurs as an 8-inch shoot in a vein 20 feet wide which outcrops on the face of a cliff, on the west side of Gunnison Canyon. The vein is formed of highly siliceous rock matter and the ore shoot which occurs slightly to the north of the center of the vein has a strike S. 78° W. and dips 85° S. 12° E. The mineral is from green to salmon pink in color and has a hardness of about 5. The presence of a large amount of silica and iron oxide undoubtedly accounts for the pink color and the hardness of the mineral.

An analysis made by the Colorado Fuel and Iron Company at Minnequa, of a sample of ore from this deposit sent them by Harry Lighte of Montrose, gave the following results.

	Per Cent
SiO_2	46.08
Al_2O_3 & Fe_2O_3	10.04
$CaCO_3$	8.67
CaF_2	33.50
$BaSO_4$	.90
	99.19

Only a small amount of work had been done in opening up the ore shoot, so that very little could be learned of the extent of the deposit, as it did not outcrop on the surface of the mesa and could not be followed down the cliff. The small opening which has been run in 10 feet on the ore shoot is rather inaccessible, being located 100 feet below the rim of the Mesa and on the edge of the canyon, where there is a sheer drop of over 2,000 feet to the river below. The deposit does not look promising because of the poor quality of the ore and its inaccessibility.

OURAY COUNTY

BARSTOW MINE

Just prior to the visit of the writer to this district a vein of fluorspar was cut in the Barstow mine at Red Mountain. This property lies within an area of rocks belonging to the Silverton volcanic series and consisting mainly of tuffs, rhyolites, and andesites. The vein was cut while drifting on the main gold-bearing vein of the Barstow about 3,300 feet, on a straight line, from the portal of the tunnel, and at a depth of 1,040 feet from the surface. Before cutting the fluorspar, the main vein of the Barstow had a strike N. 45° W., but on passing through the fluorspar its course changed abruptly to N. 15° W. The fluorspar vein which has a bearing S. 69° E. and a dip of 85° to the NE. has walls of andesite which is very little weathered. Some little faulting has occurred in the main vein and is shown by a lateral displacement of about 5 feet to the southeast, but no slickensiding or striations have resulted from this movement, and no evidence of movement was noticeable in the fluorspar vein.

The fluorspar vein varies from 3 to 5 feet in width, and on the east side of the main vein a water course through the center of the vein has formed a slight coating of silica over the fluorspar, and has deposited a solid green fluorspar next the walls. On the west side the vein contained about 5 feet of massive fluorspar, quite badly fractured, through the blasting of ore in the main vein. Up to the point of intersection of the two veins the Barstow ore was of good grade. At, and for a distance beyond that point, it was lean. But as the distance from the fluorspar vein increased the tenor of the Barstow ore gradually rose and reached the normal. Before intersecting the fluorspar vein the Barstow vein was from 12 to 14 feet wide, but beyond the fluorspar it was reduced to five feet.

The fluorspar vein had not been developed, and all samples were taken from a point at the contact with the metalliferous vein of the Barstow. The spar is massive and appears to occur as large boulders or lenses in the vein, which as seen, was irregular in width both horizontally and vertically. The fluorspar is of pale to bright green color and is extremely clean. A number of large pieces were selected and shipped to Boulder in the hope that some material suitable for optical purposes might be found. However, all the material seemed badly fractured. Part of this fracturing was evidently due to blasting in the metalliferous vein of the Barstow, and it may be that by getting well away from these conditions and carefully mining and sorting the ore, some optical fluorspar will be found. Some of the fluorspar shows a decided banding evidently due to the method of deposition. One piece an inch in diameter has 18 distinct bands varying from yellow-green to violet.

C. R. Wilfley the manager of the property told me that he believed fluorspar had been found in a level 140 feet above the occurrence here described but that we would be unable to get into that part of the mine at that time. The part of the mountain where outcrop of the fluorspar vein should be found is covered with snow the year round, so no effort was made to trace the vein on the surface. This occurrence of fluorspar at a depth of 1,040 feet, where it is found as the principal filling mineral of a fissure vein, is perhaps the greatest depth at which a true fluorspar vein has ever been found. The vein as seen shows no signs of pinching out but should continue to greater depth.

The Barstow mine has been a producer of metalliferous ores for some years and is well equipped for the production and milling of fluorspar ore. It is located one mile by wagon road southwest of the Joker Tunnel, the nearest point on the railroad, and all hauling is down hill from the mine. The railroad, however, is open only seven months out of the year and during the winter months ore would have to be hauled to Ouray for shipment. During the winter of 1917-1918 some ore was shipped from Ouray, but the heavy snow and treacherous roads made the work extremely difficult.

During the spring of 1917 the writer received a letter from C. R. Wilfley who had acted as Ouray Manager for the Engineer's Corporation, then leasing on the fluorspar vein in the Barstow. A part of this letter, as printed below, gives some very interesting information concerning the further development of the vein, while still another part describes his experiments in milling the ore.

"We did work in drifting along the fluorspar vein on both our main levels, which were about 140 feet apart vertically. The two places where we cut the spar vein on the two levels are approximately 600 feet apart horizontally. We found that at both intersections with the gold vein, the spar was too badly mixed with quartz to be mined and shipped crude, though perhaps close milling might make salable products. We got out a little ore from the lower level, then stopped there.

"On the upper level we drifted about 80 feet north or into the hanging, and perhaps half as far the other way, on the spar vein. Just as soon as we got away from the intersection we got two to four feet of fine spar and we stoped both sides of the quartz vein, getting out perhaps a thousand tons. We have not really developed this vein enough to say just what it is and what it will do, for we are barely away from the influence of the main vein. We found a tendency, as soon as we got outside of the intersection for the spar vein to turn and parallel the main vein on both sides. Not quite parallel—it still diverges at an acute angle, as shown by the intersection in the lower level so far away.

"Then we went down forty or forty-five feet below the upper or No. One Level into some drifts on the main vein which ran westerly from an old stope. This was about half way between the intersections on the main levels. We developed good spar here, showing the spar vein to be pretty continuous between the two intersections, and indicating a considerable productive area close to the main vein—'main vein' meaning the main Barstow gold vein.

"You see our development so far is small and is limited to close proximity to the main vein. I am anxious to see the spar vein developed out into the country.

"The spar vein in stopes showed somewhat pockety. Hardly true pockets, but bodies and lenses, say. This has not at all been proven nor developed, but the tendency was for a body to narrow down in going up and going horizontally, sometimes showing a horse or barren portion; then the ore would come in again and widen to good wide spar. Some of the biggest, widest ore is the best grade.

"The spar is soft and easily mined, most of it being picked down. It is a slightly sticky, somewhat sandy mass of brown clayey mud and spar. We have great boulders of fine spar in this, as well as much smaller stuff. The fine mud is somewhat aluminous but nearly all sizes contain a high percentage of spar, some of the finest stuff being pretty good. The silica is sometimes in streaks or bunches, and sometimes, when too close to the main vein, in fine sizes of separate small pieces of quartz, from half inch down to fines. We have had more or less difficulty with the quartz—but most of this was due to mining too close to the main vein. We do not know whether we can develop any big solid stopes of pure spar but are inclined to think we can. We are shut down for the winter, but have some very good showings in the stopes ready for mining.

"We shoveled snow most of the bad part of the winter and brought a good deal of spar to Ouray for shipment. Much of this spar was shipped directly as crude ore without any sorting or treatment except a little sorting of boulders of waste in the stopes. It ran 85 to 90 per cent calcium fluoride and five per cent silica, the rest being calcium carbonate, alumina, a little iron oxide, etc. We could easily wash and sort it to a higher grade. Pure specimens—rather, straight washed lump in considerable quantity could be produced at 98.5 per cent purity.

"After considerable looking over, I concluded we would not have much luck getting lens material. However, most of my investigation was of a quartzy ore which was washed on the washer; this had been shot much harder than subsequent stuff which was not washed and hence offered much less chance of looking over. I still would like to see some of our fine large lumps examined with a view to scaling and peeling down, for we might get some pretty large lenses. In general, the spar seems to be naturally pretty badly fractured."

CAMP BIRD MINE

Light green fluorspar similar to that found in the Barstow mine has been found in the Camp Bird mine. Several pieces four inches in diameter were found on the dump of one of the upper workings, and from appearances could easily have been mistaken for ore from the Barstow mine at Red Mountain, as the color and fracturing were identical. Banding was also noticed. The property was closed at the time of the writer's visit and nothing definite could be learned of the fluorspar vein.

GRIZZLY BEAR AND MICKY BREEN MINES

Fluorspar of a bright green color occurs as a gangue mineral in these two mines in Poughkeepsie Gulch where it is associated with galena, pyrite, chalcopyrite, sphalerite, rhodochrosite and quartz. A number of small crystals were examined but were too deeply colored for optical purposes.

PARK COUNTY

ALMA DISTRICT

Fluorspar in the form of cubes up to one-half inch in diameter occur as a gangue mineral associated with chalcopyrite in the Kentucky Belle and Rainbow mines. In the Rhodochrosite mine, fluorspar occurs with rhodochrosite as a gangue mineral in a sulphide ore containing galena, chalcopyrite, pyrite and tetrahedrite as the principal minerals.

The fluorspar is very clear but of a deep purple color, and does not commonly occur in crystals of sufficient size for optical purposes. The rhodochrosite separated from the other minerals is sold to curio dealers, mineral collectors and to gem collectors who cut and polish the mineral. Some fluorspar from this district has also been cut and polished.

HALLS VALLEY DISTRICT

Fluorspar has been reported as a gangue mineral in the ores of some of the old and abandoned mines. The only property working in this district was the Whale mine near the head of Halls Valley, but the ore from that property does not contain any fluorspar.

JEFFERSON DISTRICT

A well-defined vein of fluorspar is located 4 miles north of Jefferson on the east side of Guernsey Gulch, and about 400 feet above the valley. The property can be reached by road from Hoosier and from Jefferson. Some ore was mined in 1913-1914 and hauled to Hoosier, a distance of four miles, where it was shipped to the Colorado Fuel and Iron Company at Pueblo.

The property is developed by two tunnels, one 75 feet above the other, from which short drifts have been driven along the vein. The lower workings consist of a crosscut tunnel, 75 feet long, from which a drift follows the vein in a direction N. 59° E. The drift was completely closed by a cave-in and the tunnel was partly closed where the timbering had given way. The upper workings were in much better shape and consisted of a crosscut tunnel, 25 feet long, and a drift, 15 feet long, at right angles to the crosscut.

The vein fills a vertical fissure in hornblende-biotite granite, and strikes N. 59° E. At the top of the hill to the northeast the vein takes a course N. 42° E. and outcrops for a distance of 2,500 feet to a small open cut where it contains a large amount of quartz. As exposed in both workings the vein varies in width from 3 to 15 feet and contains about 15 to 18 inches of good ore.

The fluorspar in the upper workings is a light leaf green, while that in the lower workings is a very deep purple. Large pieces appeared almost black. The greater part of the leaner ore in the upper workings contains thin films of silica along the many cleavage planes. This gives a peculiar sheen to the freshly broken surfaces. The size of the dump shows that the lower workings are quite extensive, but the drift was almost entirely closed by the caving of the roof and no examination could be made. Four or five cars of ore were shipped from the property about 1913, but since that time only assessment work has been done.

PLATTE RIVER DISTRICT

Specimens of crystallized amazonite, quartz and fluorspar have been found in the vicinity of the South Platte River, northwest of Florissant. Some of the fluorspars are of considerable size and would undoubtedly make fine optical material if the owners could be induced to part with them.

SAGUACHE COUNTY

BONANZA DISTRICT

Crystals of fluorspar, both cubes and octahedrons are found associated with crystallized rhodochrosite in the sulphide ores of the Eagle mine southeast of Bonanza. Fluorspar occurs as a gangue mineral in other mines of the district, but as the deposits were of no commercial value, further investigation was not undertaken.

LIBERTY DISTRICT

Fluorspar has been developed in an open cut and in two shafts on the north slope of the ridge between Short Gulch and a small gulch south of Pole Creek, just north of Liberty, a small settlement on the east side of the San Luis Valley, and in the region of Mosca Pass. The openings are located at an elevation approximately 800 feet above Liberty and are reached by a trail starting in the gulch just north of that place. Both shafts are badly caved.

The workings expose the fluorspar in what appear to be branches of a small vein which has been developed by a small open cut in Short Gulch. A vein of fluorspar 20 inches wide, having a strike S. 52° W. and a dip 28° to the southeast, cuts the quartzites of the district. In a shallow shaft on the north end of one branch of the vein the white to green ore covers a much fractured bluish quartzite.

At the south end of this same vein, a shaft 12 feet deep exposes an ore shoot 20 inches wide. The vein here varies from S. 53° W. to S. 20° W., dips about 30° to the southeast and is 4 feet wide. The ore occurs mainly as a coating of fluorspar over irregular fragments of quartzite, and as a filling between the various fragments. It is badly fractured and varies from white to a deep green. It is covered with a white coating of material which, on analysis, proved to be mainly calcium carbonate, with some silica.

Boulders of green fluorspar up to 10 inches in diameter were found at an open cut in the other branch of the vein which is 2 feet wide and contains an ore shoot 14 inches wide. It strikes N. 82° W. and appears to join the other vein near the center ridge of the hill. No trace of either vein was found on the surface, although at the "sheep lick" a vein containing no fluorspar but having the same characteristics and direction as the first fluorspar vein described, is exposed in a small cut driven into the hillside.

SAN JUAN COUNTY

ASPEN MINE

In the Aspen mine near Silverton a deep green crystalline fluorspar is found in the lower tunnel where an 8-inch vein of fluorspar associated with some quartz, cuts one of the metalliferous veins. This vein having a strike S. 37° E. and a dip of 85° N. 42° E. cuts through the latite walls and directly across the ore shoot. The ore in the metalliferous vein was of much lower grade on both sides of the fluorspar vein, but the tenor rose as the distance from the fluorspar vein became greater. A small amount of fluorspar was found as a gangue mineral in the ore shoot near the fluorspar vein, whereas none was found at a distance from it.

A water course about 2 inches wide followed the hanging wall side of the vein, and on the side next the hanging wall rock some crystalline fluorspar was found covered with small crystals of drusy quartz. Material found on the surface of the dump where it had been exposed to the sunlight was nearly colorless while other pieces dug from a distance below the surface of the dump were of the same dark green color as that in the mine. Pieces of the colorless variety, although very clear, were somewhat fractured, and none of real optical value were found. One of the miners told of finding fluorspar in an upper level, and from his description and explanations, it was evidently from the same vein.

DAKOTA MINE

The Dakota mine has from time to time produced gold ore from a large fluorspar vein which outcrops in Boulder Gulch, near the forks of Boulder Creek. The vein at that point strikes S. 67° E. and appears to be nearly vertical. One end of the vein on passing into Tower Mountain branches out into several smaller veins that can be seen extending to the top of the mountain. The other end branches out on the north side of Boulder Mountain forming nine distinct veins which can be traced some distance beyond the top of the mountain.

The vein ranges in width from 4 to 25 feet. Its dip is generally to the south at an angle of not less than 80°. The fluorspar when mined is lilac and green but soon bleaches to a white, when left on the dump. It is very badly fractured and generally quite opaque.

The profitable part of the vein which runs as high as $60.00 in gold, is found in the fluorspar, and in a few quartz stringers. The fluorspar has a high silica content and could hardly be used for commercial purposes. The mine has not been worked for some years and the shaft through which the work was done is badly caved. The property is reached by a trail, up Boulder Canyon and can only be worked six or seven months out of the year, because of the deep snow and the danger from snow slides.

ANGLO SAXON MINE

An ore containing pyrite and chalcopyrite with fluorspar and hubnerite as gangue minerals was formerly mined in this property, as is shown by ore still on the dump. Fluorspar is found as a gangue mineral in small amounts in many other mines of the district,[39] many of which are now closed or abandoned. But at present no commercial ore is produced in the district.

SAN MIGUEL COUNTY

The presence of fluorspar is quite common in this district, where it occurs as a gangue mineral in the sulphide veins. A number of pieces up to four inches in diameter were found on the dumps of the Tomboy mine. The fluorspar occurs as a badly-fractured green-colored mineral which bleaches nearly white on exposure to the sunlight. Purington [40] says that the secondary gangue minerals of the Tomboy vein consist largely of white, coarsely saccharoidal quartz, with subordinate amounts of calcite, fluorspar and sericite. The presence of fluorspar in the veins of the Tomboy mine is regarded as a favorable sign, indicating the proximity of gold ore.

[39]Ransome, F. L., Economic geology of the Silverton quadrangle, Colorado: U. S. Geol. Survey, Silverton Folio 120, p. 29.

[40]Purington, C. W., Economic geology of the Telluride quadrangle, Colorado: U. S. Geol. Survey, Telluride Folio 57, p. 16.

TELLER COUNTY

CRIPPLE CREEK DISTRICT

Fluorspar is a common mineral in many of the ores of the Cripple Creek district, where it occurs in intimate association with quartz, forming the brilliant violet-blue ore characteristic of many of the prominent mines. It very often occurs as a filling in seams, as finely disseminated mineral, or in parallel bands in the ore.

Penrose[41] says: "The presence of fluorite may possibly have some connection with the presence of gold, but the quantity of one is no definite indication of the quantity of the other."

Very few crystals are found, and those that are found are of no use for optical purposes, as they are too deeply colored. Although the mineral is of common occurrence, no commercial deposit is found in the district.

FLORISSANT DISTRICT

Exceedingly fine specimens of fluorspar have been found in the Crystal Peak district six miles northeast of Florissant. The mineral occurs as crystals associated with microcline, amazonstone, smoky quartz, topaz and phenacite, and varies in color from green to purple. Many of the crystals appear to have lost their former color through exposure to the sun light. Crystals up to 6 inches in diameter have been found in this area of pre-Cambrian granites, but the district has been so thoroughly searched that very few are now found.

---

[41]Penrose, R. A. F., Jr., Mining geology of the Cripple Creek district, Colorado: U. S. Geol. Survey, 16th Ann. Rept., pt. II, p. 158.

CHAPTER V

MINING, MILLING AND MARKETING

ANALYSES OF COLORADO FLUORSPAR

The samples for these determinations were taken from the ore in bins, waiting haulage, in the Jamestown and Bear Creek districts, and directly from the veins in the other districts. Other analyses have been given from time to time which show similar results.

Boulder County—	Calcium Fluoride CaF_2	Silica SiO_2	Oxides, Mostly Iron (Fe_2O_3) and Alumina (Al_2O_3)	Calcium Carbonate $CaCO_3$	Barium Sulphate $BaSO_4$
Alice mine	74.18	18.17	5.02	2.02	....
Argo	86.14	9.07	3.09	1.07	....
Blue Bird	84.22	11.19	3.16	1.01	....
	79.82	12.02	5.19	2.14	....
Brown	82.76	11.91	3.72	1.37	....
Buchannan	73.13	19.47	4.16	1.78	....
Buster	81.46	10.62	4.82	2.97	....
Chancelor	86.42	8.61	3.41	1.31	....
Emmett	83.89	12.46	4.34	2.12	....
Mrs. Evans	80.87	13.06	3.93	1.79	....
L. Evans	78.12	15.76	4.32	1.27	....
Invincible	81.46	13.09	4.09	1.11	....
Markt and Atkinson	74.41	18.36	4.34	1.28	....
Poorman	70.07	21.76	4.78	2.97	....
Silver Wing	78.97	15.29	4.19	1.13	....
Terry	71.96	20.42	3.96	2.84	....
Warren	64.81	26.24	6.09	2.56	....
Geo. Walker	96.37	1.57	1.31	.67	....

	Calcium Fluoride CaF_2	Silica SiO_2	Oxides, Mostly Iron (Fe_2O_3) and Alumina (Al_2O_3)	Calcium Carbonate $CaCO_3$	Barium Sulphate $BaSO_4$
Custer County—					
Antelope Creek:					
Ore on dump	87.42	8.64	2.80	1.04	....
Vein	81.76	12.17	4.06	2.01	....
El Paso County—					
Cather Springs	80.35	14.75	3.17	1.40	....
Jefferson County—					
Augusta mine	74.97	19.31	2.78	1.97	....
Littell mine	76.42	16.13	4.87	2.16	....
Mineral County—					
Wagon Wheel Gap:					
Bin material	88.92	3.07	1.96	1.23	4.16
Sugary white	98.89	0.62	0.07	0.11	....
Brown banded	98.16	1.09	0.37	0.09	....
Green banded	98.23	0.98	0.21	0.19	....
Ouray County—					
Barstow mine:					
Green ore	97.96	1.31	0.47	0.26	....
Park County—					
Jefferson:					
Lilac green ore	69.78	25.16	3.12	1.37	....
Purple ore	81.36	11.41	5.57	1.44	....

THE MILLING OF COLORADO FLUORSPAR

The washing, screening, and concentration of Colorado fluorspar was tried for the first time during the latter part of 1917. The main purpose was that of increasing the calcium fluoride content of the ores, and at the same time decreasing the silica content.

The following letter was received from C. J. Wilfley of Ouray, describing the various experiments, which he carried on in an effort to produce and ship a better grade of fluorspar from the Barstow mine at Red Mountain.

"Part of the time we operated a washing, sorting and screening plant at Ouray, making lump, gravel and fines. We had a rather ingenious arrangement which we developed and which might be useful in other lines. We took a regular Wilfley table and discarded the deck; in its stead we put a long box about 2 feet wide, 2 deep and 18 feet long open on the top side. A few inches above the bottom we placed a false bottom of screens from 12 to 30 mesh, properly supported. The box reciprocated like a Wilfley table and minus-3-inch stuff was fed from the undersize of a grizzly.

"By giving a slight slope from the feed end and adjusting the length of table stroke the machine was capable of great variations to suit conditions of the ore and to obtain tonnage. Over the first half were a number of water sprays which disintegrated the mud and washed it through the screens as fines, the washings being removed through spouts in the bottom. The latter half of the machine was a very good sorting table, where we threw out the waste.

"We were able also to screen out stuff as coarse as, I think, three-eighths inch, though the screening was not very efficient without a special spray over this screen.

"But little other mineral was found with the spar, although practically all of it was accompanied by a little more than traces of lead and by quite a little pyrite. Much of this was in soft decomposed gangue or scattered through the vein, and it was all removed through the fine screens. I concentrated the fines several times for an iron concentrate; this assayed a little gold and several ounces silver with very little copper or lead, but was not a commercial product."

In the Chesbro Mill at Boulder, the fluorspar ores were put through a set of rolls, then over concentrating tables and slimers, after which the concentrates were allowed to stand and later were shipped while still wet.

The Hoffnung Mill at Jamestown was being overhauled early in the spring of 1918, and it was announced that the mill would produce fluorspar concentrates as soon as the work was finished. The mill is equipped with a crusher, five stamps, a concentrating table, and a slimer.

At Wagon Wheel Gap, a large amount of fluorspar and barite was noticed in the dump at the upper terminal. A considerable tonnage of both of these minerals could be produced by either jigging or method of concentrating the dump, while at the same time the fluorspar content of "fluorite-barite" ores could be raised, and the barite saved by the same treatment.

Trial runs were being made on ore from a number of properties during the spring of 1918, and it was rumored that several old mills in the Jamestown district were to be reopened for the commercial treatment of ores from that district.

GRADES OF FLUORSPAR

Fluorspar is classed as lump, gravel, ground, and concentrates. The lump and gravel ores are usually divided into three classes while the ground fluorspar is divided into four grades. "Gravel" is a term now used to classify all that product resulting from the breaking up of lump, through natural causes, and the crushed fluorspar from mills.

The highest grade No. 1 fluorspar is usually white or colorless, and should run 96 per cent or more in calcium fluoride. The remainder consists of silica, iron oxides, alumina, calcium and magnesium carbonates, alkalies, hydrocarbons, and moisture. Dark-colored fluorspars usually run higher in their silica and hydrocarbon contents, especially if shattered, or iron stained, since in that condition silica filters into the small cracks and increases the detrimental products. It is used mainly in the chemical industry.

No. 2 grade includes colored fluorspar and will run 90 per cent or over in calcium fluoride, and less than 4 per cent of silica. Colored fluorspar and crushed mill products nearly all fall into this class. This grade is used in the production of ferrosilicon and ferromanganese, and in the basic open hearth steel furnaces, to give increased fluidity to the slag and reduce the phosphorus and sulphur contents.

No. 3 grade includes all the fluorspar containing from 60 to 90 per cent of calcium fluoride, and in excess of 4 per cent of silica. Unwashed gravel belongs to this class as does fluorspar mixed with excessive amounts of calcite, limestone, barite, and mill dirt. This product is used mainly as a flux in the smelting of iron; and in brass foundries, where it is of value in making the alloy more fluid, and where it also permits the use of larger quantities of low grade scrap, because it carries phosphorus, sulphur and other impurities into the slag.

Ground fluorspar is nearly all made from the No. 1 grade of fluorspar, and is classed as Extra No. 1, No. 1 and No. 2. No 1 ground contains 98 per cent of calcium fluoride and about one per cent of silica. Extra No. 1 ground contains less than one per cent of silica, while No. 2 ground contains from 96 to 98 per cent of calcium fluoride and up to two per cent of silica. No. 3 ground is an English product corresponding to No. 3 fluorspar. The ground fluorspar averages about 85 mesh in fineness and is used in the manufacture of glass, enamels, and terra cotta. It is also used in the chemical industry.

Most of the fluorspar produced in Colorado is classed as "gravel" and would be placed in the No. 3 class, although some No. 1 and No. 2 have been produced from the Wagon Wheel Gap and Barstow deposits.

The concentrates now being produced in Colorado will most likely be placed in the No. 3 class, although some may be classed as No. 2. The physical character of the product will necessitate the making of an entirely new class for this material.

FLUORSPAR PRODUCTION

During 1917 the fluorspar production of Colorado increased to 17,104 short tons,[42] valued at $196,633.00, an average of $11.50 per ton. This tonnage is a decided increase over the fluctuating and relatively small tonnage produced in previous years.

During the early spring of 1918 the demand for fluorspar was good, and the activity in the Colorado fields had developed considerably over that of 1917, when Colorado produced 7.8 per cent of the total tonnage of fluorspar mined in the United States.

The production of fluorspar in the United States during 1917 amounted to 218,828 short tons; valued at $2,287,722.00. This production brought an average price of $10.40 per ton, as compared to an average price of $6.37 per ton, paid during 1913, the year previous to the war.

Imports decreased for several years, prior to the war, and reached a minimum in 1915. During 1917 manufacturers were forced to take imports, on account of difficulties encountered in the delivery of American fluorspar, and 13,616 short tons were imported during that year. The imported fluorspar brought an average price of $8.42 per ton, which was somewhat lower than the average price paid for American fluorspar. The American product was, however, of a higher average grade than the imported fluorspar.

The accompanying diagram, showing the production of fluorspar in the United States, and imports from 1910 to 1917, was taken from Mineral Resources of the United States, 1917, part II, page 298.

---

[42] Burchard, Ernest F., U. S. Geol. Survey, Min. Res., pt. II, pp. 293-304, 1917.

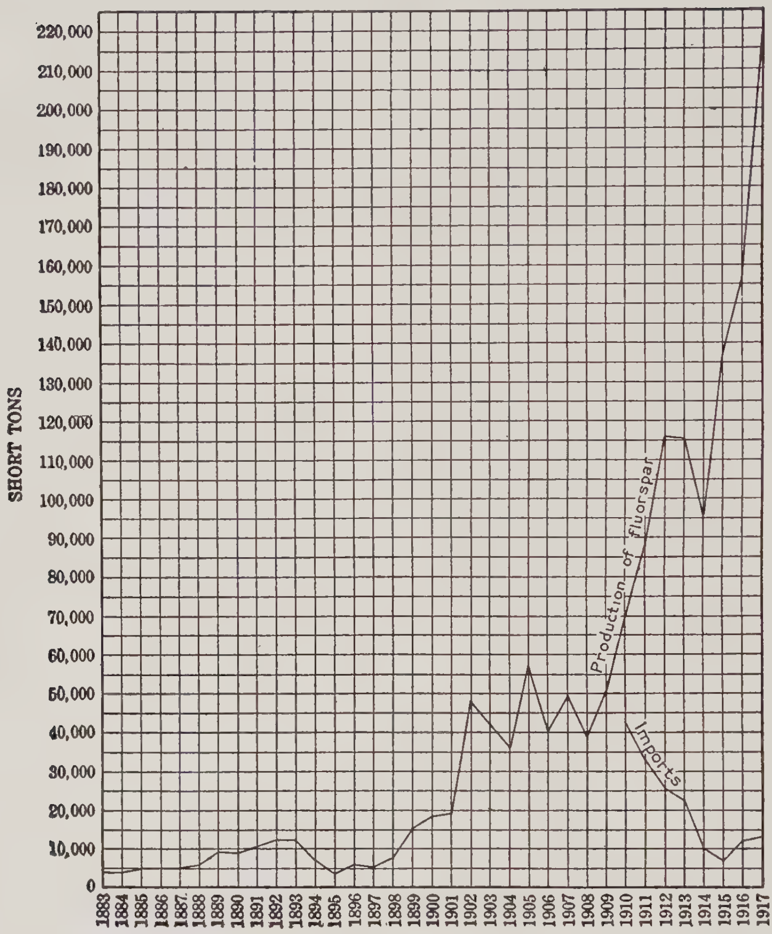


FIGURE 10.—Diagram showing production of fluorspar in the United States, 1883–1917, and imports 1910–1917.

MARKETS FOR FLUORSPAR

Fluorspar used in the various industries is bought directly from the producer, or through dealers in that product. The United States Geological Survey[43] has published the following list of buyers, to aid the producer in marketing his ore.

[43]Burchard, Ernest F., U. S. Geol. Survey, Min. Res., pt. II, pp. 293-304, 1917.

BUYERS OF FLUORSPAR

A. D. Mackay, 130 Pearl Street, New York, N. Y.
Alan Wood Iron & Steel Co., Philadelphia, Pa.
Allegheny Steel Co., Pittsburgh, Pa.
Aluminum Ore Co., East St. Louis, Ill.
Aluminum Co. of America, Pittsburgh, Pa.
American Cyanamid Co., New York, N. Y.
American Stamping & Enameling Co., Bellaire, Ohio.
American Tube & Stamping Co., Bridgeport, Conn.
American Steel & Wire Co., Cleveland, Ohio.
Bethlehem Steel Co., Bethlehem, Pa.
Binney & Smith Co., 81 Fulton Street, New York, N. Y.
Brier Hill Steel Co., Youngstown, Ohio.
L. H. Butcher & Co., San Francisco, Calif.
Cambria Steel Co., Pittsburgh, Pa.
Carnegie Steel Co., Pittsburgh, Pa.
Central Pigment Co., Strand Building, Forty-seventh Street and Broadway, New York, N. Y.
George W. Chesebro, Boulder, Colo.
Chrome Steel Works, Chrome, N. J.
J. G. Clark, Boulder, Colo.
Colorado Fuel & Iron Co., Denver, Colo.
Commercial Chemical Co., 1100-1110 Wasbash Avenue, Chicago, Ill.
Debevoise-Anderson Co. (Inc.), 56 Liberty Street, New York, N. Y.
Eagle Glass & Manufacturing Co., Wellsburg, W. Va.
Engineers Corporation, Boulder, Colo.
Ferro-Alloy Co., Denver, Colo.
Feuchtwanger & Co., New York, N. Y.
Ford Motor Co., Detroit, Mich.
Fostoria Glass Co., Moundsville, W. Va.
Franco-American Chemical Co., New York, N. Y.
General Chemical Co., Pittsburgh, Pa.
Glover Machine Works, Marietta, Ga.
Gulf States Steel Co., Birmingham, Ala.
Hamilton Facing Mill Co. (Ltd.), Hamilton, Ontario.
Hazel-Atlas Glass Co., Wheeling, W. Va.
Harshaw-Fuller & Goodwin Co., Cleveland, Ohio.
Illinois Steel Co., Chicago, Ill.
Inter-State Iron & Steel Co., Chicago, Ill.
J. M. Jackson, Rosiclare, Ill.
Jones & Laughlin, Pittsburgh, Pa.
Kentucky Fluor Spar Co., Marion, Ky.
La Belle Iron Works, Steubenville, Ohio.
La Clede Steel Co., Alton, Ill.
Lackawanna Steel Co., Lackawanna, N. Y.
E. J. Lavino Co., Philadelphia, Pa.
Lee Mineral Co., 201 Park Avenue, Baltimore, Md.
Lower California Metals Co., Nogales, Ariz.
Lukens Iron & Steel Co., Coatesville, Pa.

Matthew Addy Co., Cincinnati, Ohio.
McKinney Steel Co., Cleveland, Ohio.
Metalores Corporation, 56 Pine Street, New York, N. Y.
Midvale Steel & Ordnance Co., 14 Wall Street, New York, N. Y.
National Enameling Co., St. Louis, Mo.
National Ore & Metals Co., 601-602 Symes Building, Denver, Colo.
National Sales Co., Cincinnati, Ohio.
Noble Electric Steel Co., San Francisco, Cal.
Pacific Coast Steel Co., Seattle, Wash.
Penn Seaboard Steel Corporation, Philadelphia, Pa.
J. S. Perry, 520 South Canal Street, Chicago, Ill.
Pine Iron Works, Pine Forge, Pa.
Pittsburgh Crucible Steel Co., Pittsburgh, Pa.
Pittsburgh Steel Co., Pittsburgh, Pa.
A. H. Reed, Marion, Ky.
Republic Iron & Steel Co., Youngstown, Ohio.
J. C. Rice, Dome, Ariz.
Roberts Fluor Spar Co., Marion, Ky.
Rogers, Brown & Co., Cincinnati, Ohio.
Sizer Forge Co., Buffalo, N. Y.
Southern Minerals Co., Hopkinsville, Ky.
Frederick B. Stevens, Detroit, Mich.
J. D. Taylor, St. Louis, Mo.
Chas. S. Trench & Co., 81-83 Fulton Street, New York, N. Y.
Trumbull Steel Co., Warren, Ohio.
Tungsten Products Corporation, Boulder, Colo.
United States Stamping Co., Moundsville, W. Va.
Whitaker-Glessner Co., Portsmouth, Ohio.
John C. Wiarda & Co., Green, Provost and Freeman Streets, Brooklyn, New York.
H. L. Wilson, Marion, Ky.
Woods, Huddart & Gunn, San Francisco, Cal.
Youngstown Steel Co., Youngstown, Ohio.

APPENDIX.

FLUORSPAR DEPOSITS OF THE UNITED STATES

During 1917, Hardin and Pope counties in Illinois led the United States in the production of fluorspar. Kentucky stood next to Illinois in production, with Crittenden, Livingston and Caldwell as producing counties, and some encouraging prospecting was being done in Mercer County. Fluorspar was produced as a jig product incidental to the concentrating of lead and silver ores, at Castle Dome, Yuma County, Arizona.

Near Deming, New Mexico, some ore was mined and the finding of favorable deposits was reported from San Bernardino County, California. At Albermarle, Virginia, fluorspar is produced as a by-product in the milling of lead and zinc ores. Fluorspar has been reported as occurring in commercial quantities in Smith and Trousdal counties in central Tennessee. In New Hampshire a small tonnage is being produced.

FLUORSPAR IN ENGLAND[44]

In England fluorspar occurs abundantly in the Carboniferous limestone and its associated shale, limestone, and sandstone of the Yoredale group. The whole of the present British production comes from these strata, where it is found as the gangue of metalliferous veins. It is usually associated with calcspar, quartz, or barytes, though this is not universally the case.

Derbyshire leads in the production of fluorspar, and Durham takes second place. The greater part of the production is obtained by working the old lead-mine dumps, in which the fluorspar exists as the waste material of lead-mining operations dating from remote times. Some mines are now producing fluorspar, but the tonnage obtained in that way is far less than that produced by working the dumps.

Fluorspar from the Blue John mine at Castleton, Derbyshire is noted for its unique characteristics. Ore from that property is cut into vases, the color and the results obtained being very extraordinary.

[44] The Engineer, London, pp. 185-187, Aug. 21, 1908.

A very interesting publication by the Geological Survey of Great Britain,[45] issued in 1916, deals with the fluorspar resources of Great Britain . This report which is brief, consists of a preface and three chapters treating of the supply, uses, statistics, and technology of the deposits.

In stating the sources of supply the following was given:

"Although some thousands of tons of fluorspar are annually raised in France and Germany (Bavaria and Saxony), and a little also in Spain, the bulk of the world's supply comes from Britain and the United States, the latter being also the chief consumer."

Notes from this publication will be found on page 317 of the Mineral Resources of the United States, United States Geological Survey, 1916, pt. 2, pp. 309-325.[46]

FLUORSPAR IN CANADA

Shipments of fluorspar have been made from Madoc, Ontario, and others are reported from British Columbia. During 1916 the production from Ontario amounted to 1,284 tons.[47]

---

[45]Carruthers, R. G., Pocock, R. W., Wray, D. A., with contributions by Dewey, H., and Bromehead, C. E. N., Fluorspar: Special reports on the mineral resources of Great Britain, vol. 4 (Geol. Survey Mem.), p. 38, 1916.

[46]Burchard, E. F., Fluorspar in Great Britain: U. S. Geol. Survey, Min. Res., pt. II, pp. 317-322, 1916.

[47]Preliminary report on the mineral production of Canada during 1916, Canada Dept. Mines. Mines Branch.

BIBLIOGRAPHY OF COLORADO FLUORSPAR

Bancroft, Howland, and Irving, John D., Geology and ore deposits near Lake City, Colorado: U. S. Geol. Survey, Bull. 478, p. 46, 1911.

Bastin, Edson S., and Hill, James M., General features of the economic geology of Gilpin county and adjacent parts of Clear Creek and Boulder counties, Colorado: U. S. Geol. Survey, Prof. Paper 94, pp. 105, 106, 114, and 115, 1917.

Burchard, E. F., Our mineral supplies. Fluorspar: U. S. Geol. Survey, Bull, 666, pp. 1-8, 1918.
Fluorspar in Colorado: Min. Sci. Press, pp. 258-261, Aug. 21, 1919.

Emmons, S. F., Geology and mineral industry of Leadville, Colorado: U. S. Geol. Survey, Mon. 12, p. 527.
Geology of Silver Cliff and the Rosita Hills, Colorado: U. S. Geol. Survey, 17th Ann. Rept., pt. II, p. 470.
Description of the Elk Mountains, Colorado: U. S. Geol. Survey, Anthracite-Crested Butte Folio 9, p. 2.

Emmons, W. H., and Larson, E. S., A preliminary report on the geology and ore deposits of Creede, Colorado: U. S. Geol. Survey, Bull. 530, pp. 42-65.

The hot springs and the mineral deposits of Wagon Wheel Gap, Colorado: Econ. Geol., vol. 8, pp. 235-246, 1913.

Finlay, G. I., Description of the Colorado Springs quadrangle, Colorado: U. S. Geol. Survey, Colorado Springs Folio 203, p. 15.

Hayden, F. V., Geographical survey of the territories: U. S. Geol. Survey, 3rd. Ann. Rept., p. 209, 1869.
Geographical survey of the territories: U. S. Geol. Survey, 10th Ann. Rept., pp. 142-143, 1876.

Hubbell, A. H., War minerals of Colorado: Eng. & Min. Jour., p. 384, Aug. 31, 1918.

Irving, J. D., and Emmons, W. H., Economic Geology of the Needle Mountains, Colorado: U. S. Geol. Survey, Needle Mountains Folio 131, p. 12.

Larsen, E. S., and Wells, R. C., Some minerals from the fluorite-barite vein near Wagon Wheel Gap, Colorado: Nat'l. Acad. Sci., vol. 2, p. 360, July, 1916.

Lindgren, W., and Ransome, F. L., Geology and gold deposits of the Cripple Creek district, Colorado: U. S. Geol. Survey, Prof. Paper 54, pp. 3, 4, 6, 47, 100, 114, 122, 160, 190, 218-219, and 493.

Lunt, Horace F., A fluorspar mine in Colorado: Min. & Sci. Press, pp. 925-926, Dec. 18, 1915.

Mineral Resources published by the U. S. Geol. Survey. See years 1882-1918.

Penrose, R. A. F., Description of the Cripple Creek special map: U. S. Geol. Survey, Pikes Peak Folio 7, p. 7.
Mining geology of the Cripple Creek district, Colorado: U. S. Geol. Survey, 16th Ann. Rept., pt. II, pp. 126, 157-159.

Purington, C. W., Economic geology of the Telluride quadrangle, Colorado: U. S. Geol. Survey, Telluride Folio 57, p. 16.
Economic geology of the LaPlata quadrangle, Colorado: U. S. Geol. Survey, LaPlata Folio 60, p. 13.
Preliminary report on the mining industries of the Telluride quadrangle, Colorado: U. S. Geol. Survey, 18th Ann. Rept., pt. III, pp. 790, 822.

Ransome, F. L., Economic geology of the Rico quadrangle, Colorado: U. S. Geol. Survey, Rico Folio 130, p. 15.
Ore deposits of Rico Mountains: U. S. Geol. Survey, 22nd Ann. Rept., pt. II, p. 252.
Economic geology of the Silverton quadrangle, Colorado: U. S. Geol. Survey, Silverton Folio 120, p. 29.
Economic geology of the Silverton quadrangle. Colorado: U. S. Geol. Survey, Bull. 182, pp. 74, 136, and 163.

Smith, J. Alden, Fluorspar: State Geologist's Rept., pp. 34 and 55, 1880.
Fluorspar: State Geologist's Rept., p. 136, 1881-1882.

Spurr, J. E., and Garry, G. H., and Ball, S. H., Economic geology of the Georgetown quadrangle, Colorado: U. S. Geol. Survey, Prof. Paper 63, pp. 65, 96, 136, 137, 142, 153-154.

BIBLIOGRAPHY OF FLUORSPAR IN THE UNITED STATES

Adolph, W. H., Observations upon quantitative determination of fluorine: Am. Chem. Soc. Jour., pp. 2500-2515, Nov., 1915.

Bain, H. F., Principal American fluorspar deposits: Min. Mag., pp. 115-119, Aug,, 1905.
Fluorspar deposits of southern Illinois: U. S. Geol. Survey, Bull. 255, 1905.

Bidtel, E., Valuation of fluorspar: Jour. Ind. & Eng. Chem., 1912.

Burchard, E. F., Fluorspar mining at Rosiclare, Illinois: Eng. & Min. Jour., pp. 1088-1090, Dec. 2, 1911.
Fluorspar in New Mexico: Min. & Sci. Press, pp. 74-76, July 15, 1911.
A modern fluorspar mining and milling plant: Iron Trade Rev., vol. 49, pp. 1046-1051, 1911.

Canadian Min. Jour., Fluorite mining in Ontario: pp. 206-207, June 15, 1918.

Clark, L., Critical study of the potassium and sodium double salts of lead tetrafluoride as sources of fluorine: Am. Chem. Soc. Jour., vol. 41, pp. 1477-1491, 1919.

Clarke, F. W., The data of geochemistry: U. S. Geol. Survey, Bull. 330, pp. 16, 91, 149, 240, 273, 274, 461, 500.
The data of geochemistry: U. S. Geol. Survey, Bull. 616, pp. 16, 68, 119, 192, 261, 271, 335, 336, 504, 582.

Dana's System of Mineralogy: Fluorite (fluorspar).

Darton, N. H., and Burchard, E. F., Fluorspar near Deming, New Mexico: U. S. Geol. Survey, Bull, 470, pp. 533-545.

Dinwiddie, J. G., Determining fluorine in soluble fluorides: Eng. & Min. Jour., pp. 1067-1068, June 16, 1917.

Directory of steel manufacturers of the United States. A. B. C. of iron and steel: Iron Trade Rev. Also see Am. Iron & Steel. Inst.

Egglestone, W. M., The occurrence and commercial uses of fluorspar: Inst. Min. Eng., Trans., pt. II, vol. 35, pp. 236-268, 1908. London, England.

Emmons, S. F., Fluorspar deposits of southern Illinois: Am. Inst. Min. Eng., Trans., vol. 21, pp. 31-53, 1893.

Eng. and Min. Jour., Behavior of fluorspar in smelting: p. 793, Oct. 28, 1905.

Eng. and Min. Jour., Fluorite for optical purposes: p. 522, Mar. 16, 1918.

Fohs, F. J., Fluorspar deposits of Kentucky, with notes on production, mining, and technology of the mineral: Kentucky Geol. Survey, Bull. 9, 1907.
Kentucky fluorspar and its value in the iron and steel industries: Am. Inst. Min. Eng., Trans., vol. 40, p. 261, 1909.
The fluorspar, lead, and zinc deposits of western Kentucky: Econ. Geol., pp. 377-386, June, 1910.

Gardner, Henry A., Report on impregnated panel tests and fire retardant paints: Paints Mfg. Assn., of the U. S., Bull. 51, Feb., 1916.

Gautier, A., and Clausman, P., Artificial fertilizer, studies on the influence of fluorides on plants: Sci. Am. Sup., p. 95, Aug. 8, 1919.

Goldmerstein, L., Prolonging the life of the Bessemer process: Iron Age, vol. 93, pp. 250-251, Jan. 22, 1914.
The fluorine process in the open-hearth: Iron Age, vol. 93, pp. 724-725, Mar. 19, 1914.

Howe, H. M., Metallurgy of Steel, pp. 61, 63.

Ingalls, W. R., The metallurgy of zinc and cadmium, pp. 34 and 213.

Keeney, R. M., Fluorspar in electric smelting of iron ore: Min. & Sci. Press, pp. 335-336, Aug. 29, 1914.

Kneeland, E., A method for the determination of fluorine in an ore or slag: Eng. & Min. Jour., p. 1212, Dec. 30, 1905.

Lang, H., Fluorite in smelting: Min. & Sci. Press, vol. 108, p. 492, Mar. 21, 1914.

Luedeking, C. C., History and present methods of fluorspar mining in Illinois: Jour. Ind. & Eng. Chem., pp. 554-555, June, 1916.

Martin, Henry G., Barium and sulphur in fluorspar: Jour. Ind. & Eng. Chem., 1909. Also Iron Age, Aug. 5, 1909.

Mathers, F. C., Means, K. S., and Richard, B. F., Electro-deposition of antimony from fluoride baths containing addition agents: Am. Electro-chemical Soc., Trans., pp. 293-302, vol. 31, May 5, 1917.

Miller, A. M., The lead and zinc bearing rocks of central Kentucky: Kentucky Geol. Survey, Bull. 2, 1905.

Mineral Industry; Fluorspar: See years 1892-1918.

Mineral Resources; published by the U. S. Geol. Survey. See years 1882-1918.

Moissan's researches on fluorine: Jour. Frankl. Inst., vol. 152, pp. 123-140.

Nevins, J. Nelson, The Castle Dome lead district, Arizona: Min. & Sci. Press, pp. 854-855, vol. 104, 1912.

Packard, R. L., Mineral resources of the United States. Aluminum: U. S. Geol. Survey, 16th Ann. Rept., pt. III, p. 540.

Patterson, T. A., Conductivity of fluosilicic acid and lead fluosilicate: Met. & Chem. Eng. Jour., vol. II, pp. 670-672, Dec., 1913.

Pisan, F., Determination of fluorine: Eng. & Min. Jour., p. 1139, Dec. 30, 1916.

Pogue, Joseph E., Optical fluorite in southern Illinois: Bull. 38 (extract), pp. 1-8, 1918.

Production of fluorspar in Great Britain: Min. Mag., (London) pp. 283-284, May, 1916.

Queneau, A. L., Composite metallurgical vessels: Eng. & Min. Jour., vol. 82, No. 15, pp. 677-679, 1906.

Rawn, E. V., Kentucky fluorspar mining: Iron Age, vol. 103, p. 818, Mar. 27, 1919.

Reed, A. H., Fluorspar in Kentucky and Illinois: Eng. & Min. Jour., pp. 164-165, Jan. 17, 1914.

Scarcity of fluorspar: Iron Age, vol. 101, p. 563, Feb. 28, 1918.

Shimer, W. R., Fluorspar and basic slags: Iron Age, vol. 95, p. 397, 1915.

Smith, W. S. T., and Ulrich, E. O., Lead, zinc, and fluorspar deposits of western Kentucky: U. S. Geol. Survey, Bull. 213, pp. 205-213.

Sweetzer, A L. Fluorspar market and the local supply: Eng. & Min. Jour., pp. 1031-1032, Dec. 14, 1918.

Steinkoenig, L. A., Relation of fluorine in solids, plants and animals: Jour. Ind. & Eng. Chem., pp. 463-465, May, 1919.

Teesdale, C. H., Use of fluorides in wood preservation: vol. 3, No. 4, and vol. 4, No. 1. Reprinted from Wood-Preserving.

The Engineer (London), Fluorspar: pp. 185, 187, Aug. 21, 1908.

Thorp, L., and Wildman, E. A., Synthesis in the diphenylmethane series: Am. Chem. Soc. Jour., pp. 372-377, Feb., 1915.

Van Hise, C. R., Alteration of fluorspar. A treatise on metamorphism: U. S. Geol. Survey, Mon. 47, p. 216, 1904.

Wagner, C. R., and Ross, W. H., A modified method for the determination of fluorine with special application to the analysis of phosphates: Jour. Ind. & Eng. Chem., vol. 9, pp. 1116-1123, Dec., 1917.

Watson, T. L., Lead and zinc deposits of Virginia: Virginia Geol. Survey, Bull. 1, p. 42, 1905.

INDEX

KOP 19
15w

Clay Welty
8410 West 108th Ave.
Route #1
Broomfield, Colorado 80020